Electricity. II

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Ch Toor.

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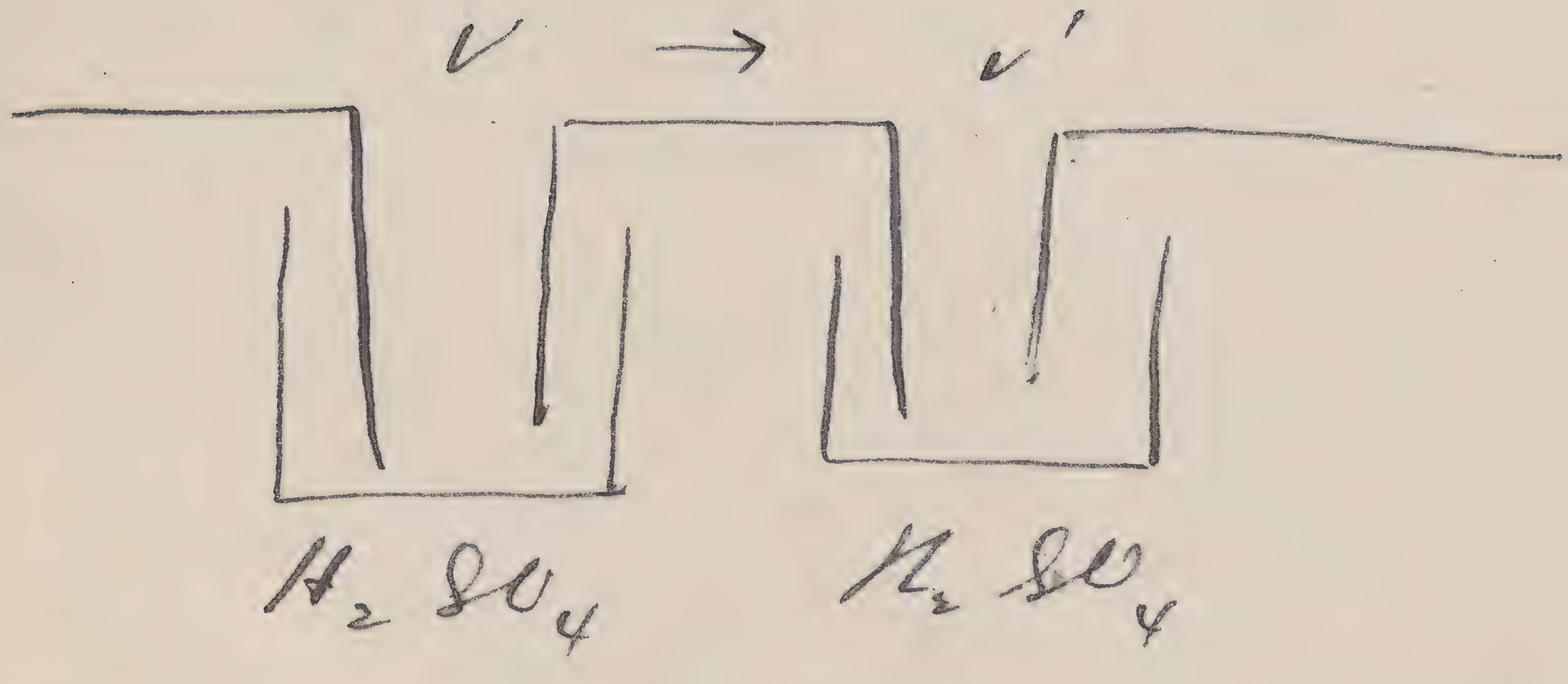
Joule's law: the heating effect for a given consumption of zinc is constant whatever the resistance of the circuit.

DSI



The fall in potential is different for the two cases.

QV = work of electrog. of H_2SO_4
QV' = " " " H_2SO_4

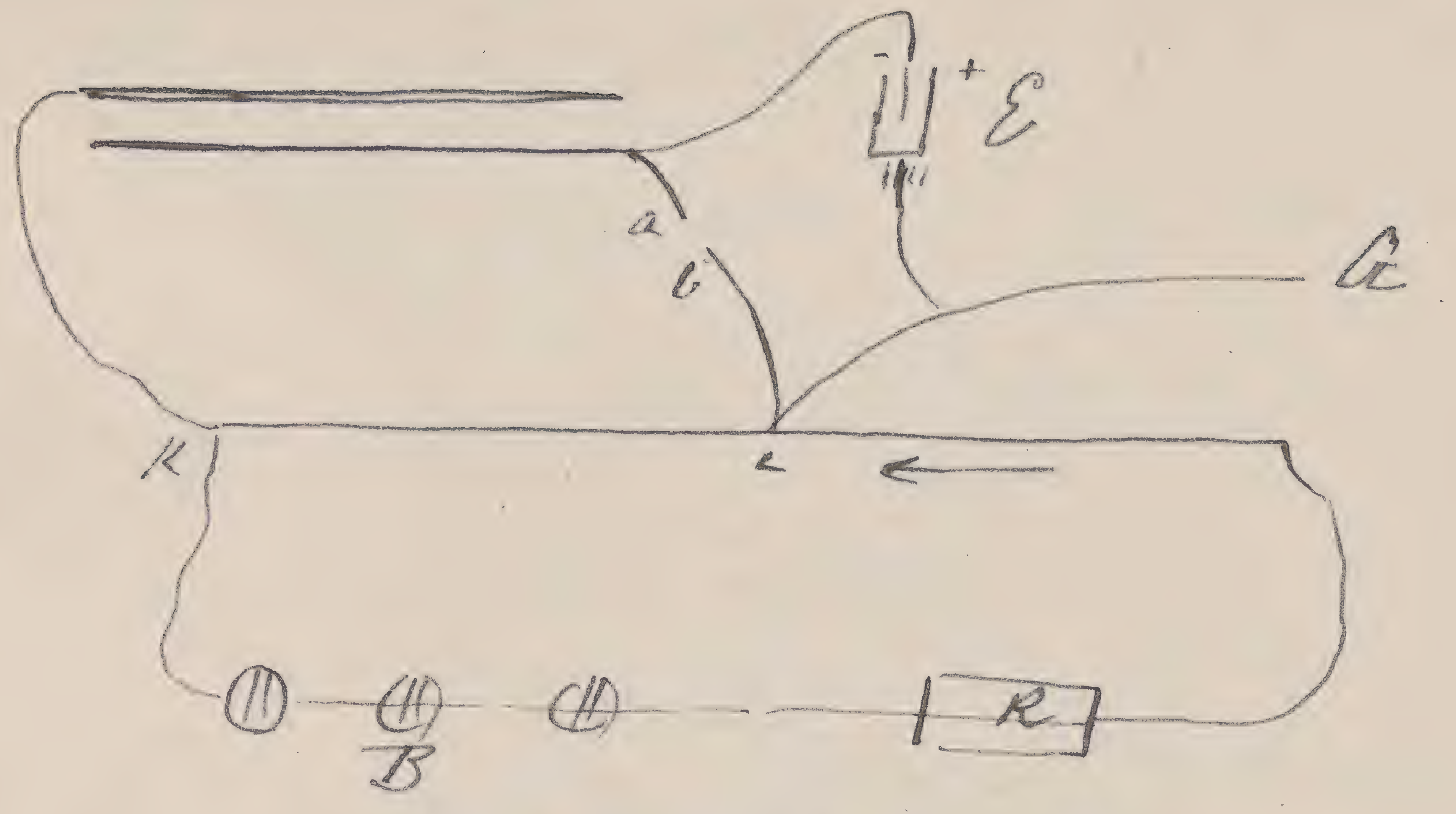
The work is affected by the secondary chemical action, helping it in some cases, and hindering in others.

Contact E.M.F between metals.

Kohlrausch method as already explained.

Compensation method.

MSS 837B v.2
RB NMAH



E = an electrometer.

When the gap ab is closed the two plates are brought into a circuit. The difference of potential between k and l is

$$V' - V = cR.$$

and the plate with which l is connected would tend to come to a higher potential than other. But if the plates are of different metals, they may be so placed that the contact action shall just balance this effect.

I Electrolytes may be decomposed wh. may be simple or compound.

This possible to deposit alloys, as bronze, brass.

II In most metallic solutions the metal is deposited at the cathode

III Owing to secondary action metals of the alkalis and alkali earths are not ordinarily deposited, but may be obtained from strong solutions.

IV From mixed solutions the least electro-positive metal is deposited first, unless a very strong current.

V The liberated ions appear only

at the electrodes.

For each electrolyte a minimum E. M. F is necessary.

There is no opposing E. M. F when the same metal is being taken from the anode and deposited upon the cathode.

Under great pressure gases may be prevented from being electrolyzed. At about 300 atmos. water ceases to be.

Ohms law holds for electro.

The quantity of work done

is $qV = Jh$

$$V = \frac{Jh}{q}$$

h = heat of combination

Magnetism & Electro-Mag

Unit strength of pole is one that when placed at one cm. from pole of same kind will repel it with one dyne.

$$F = \frac{mm_1}{r^2}$$

Mag. density is the quantity of mag. per unit surface.

Lines of force and equipotential surfaces are similar to those of electricity.

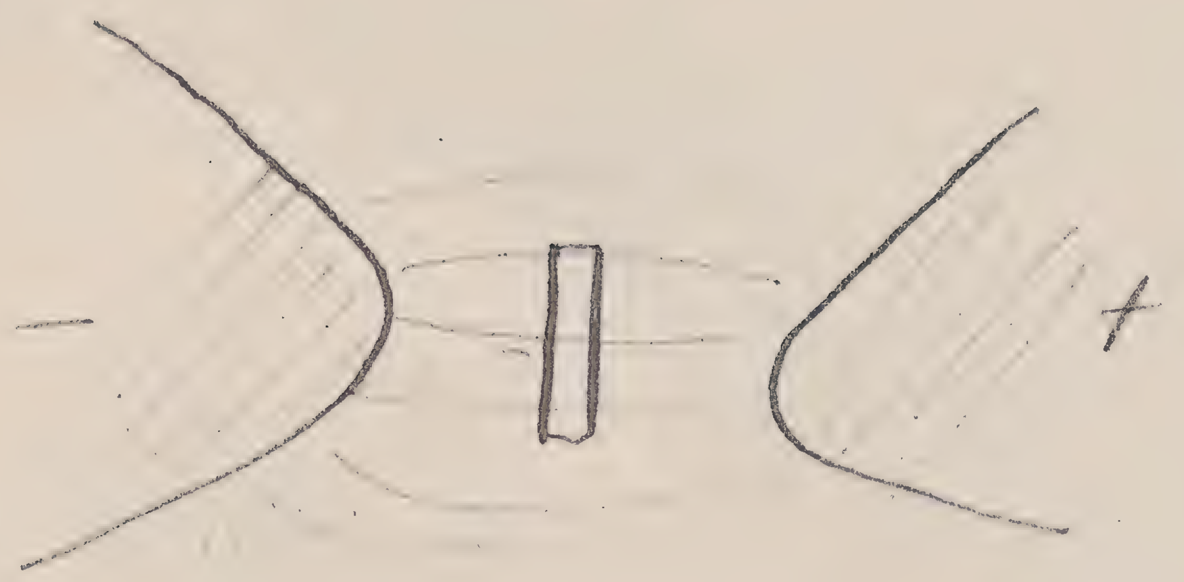
$$V = \Sigma \frac{m}{r} + c$$

We must always have an equal quantities of + and −, magnet. in the one body.

A paramag. body when placed in a field of force always moves in the direction in wh. the mag. intensity of the mag. force increases most rapidly.

R = resultant force.

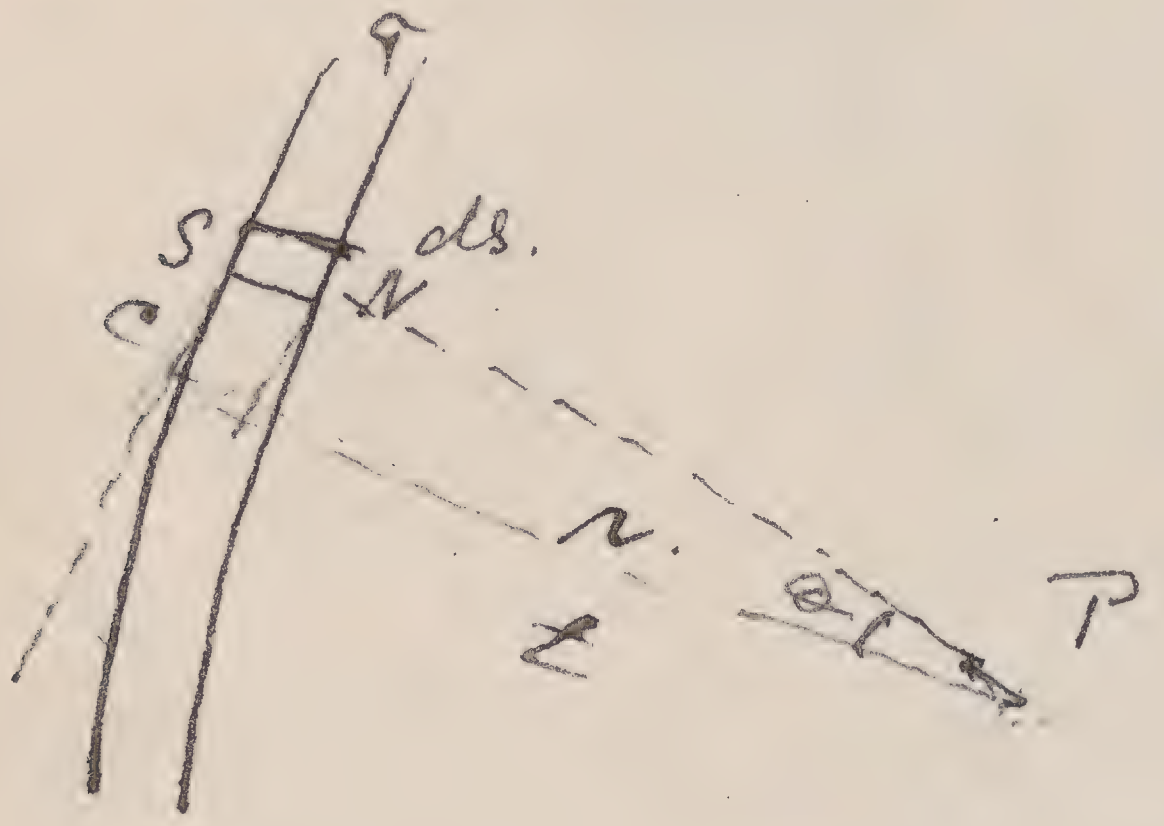
Dia-mag. bodies move from regions of greater intensity to regions of less intensity, and move along the line of most rapid change.



Bar of Ice

S
r
q
C
x
P

The potential due to a thin magnetic shell.



$$V = \Sigma \frac{m}{r}.$$

ρ = quantity of mag. per unit surface.

$\rho \frac{dS}{r}$ = potential due to north mag. ~~of a~~ elementary mag.

$-\rho \frac{dS}{r'}$ = potential due to South end of mag.

$$\therefore V = \Sigma \left(\frac{\rho dS}{r} - \frac{\rho dS}{r'} \right)$$

$$= -\Sigma \left[\frac{d(\rho \frac{dS}{r})}{dt} q \right]$$

$$= \int \frac{d\left(\frac{\rho\, dS}{r}\right)}{dr} \frac{dr}{dt} = -\frac{\rho\, dS}{r^2} \cdot \frac{t}{r}$$ by diff

for $r^2 = c^2 + t^2$

$\therefore r\,dr = t\,dt \quad \therefore \frac{dr}{dt} = \frac{t}{r} = \cos\theta$

$$-\frac{\rho\, dS}{r^2} \cos\theta$$

but $\frac{dS}{r^2}\cos\theta$ = elementary solid

∠ at p.

$$V = +\Sigma\left(\rho\tau\, d\Omega\right)$$

assuming that the product of ρ and τ is constant we have

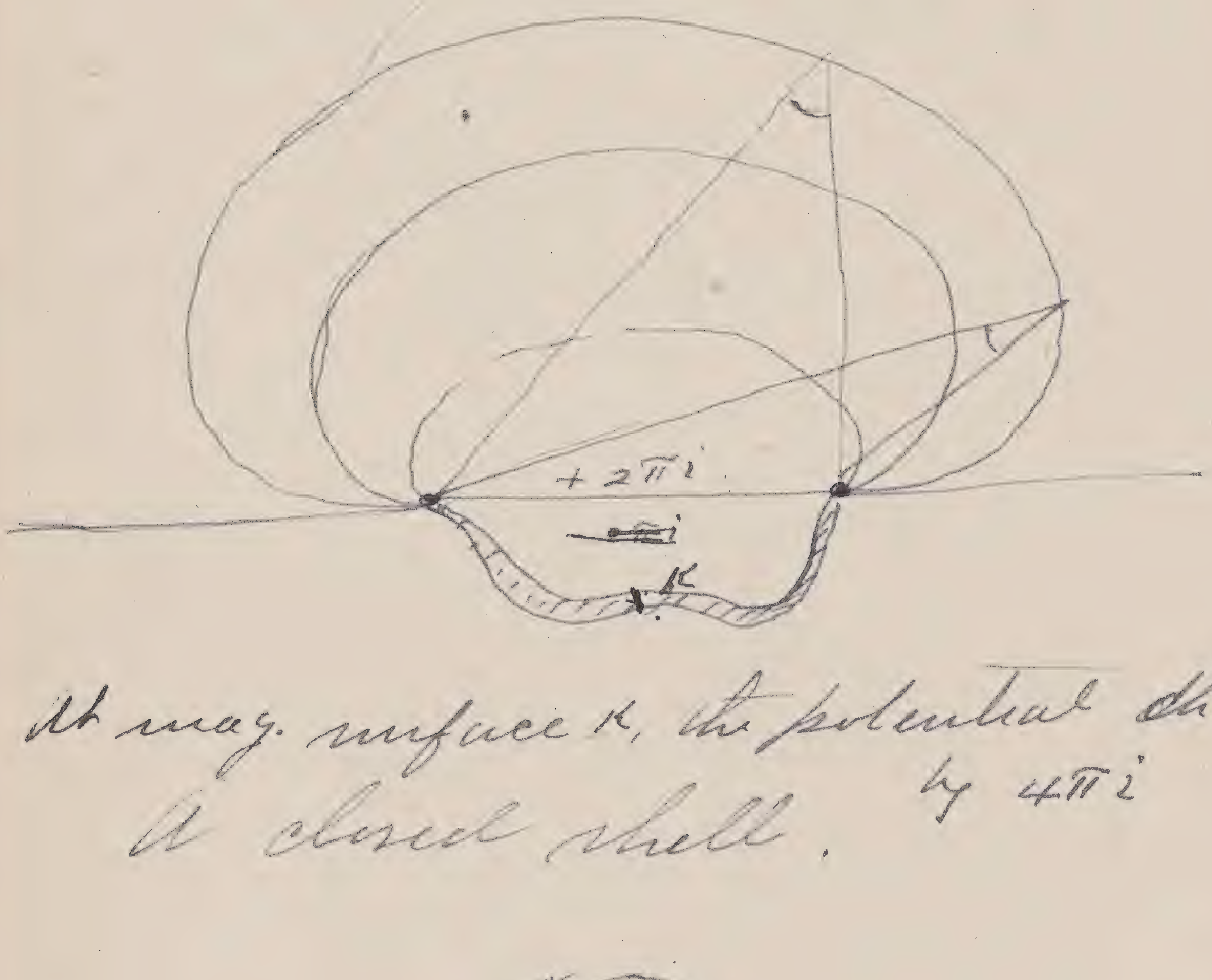
$$V = +\rho\tau\Omega.$$

$\rho\tau$ is called the strength of the shell, called i.

$$V = +i\Omega$$

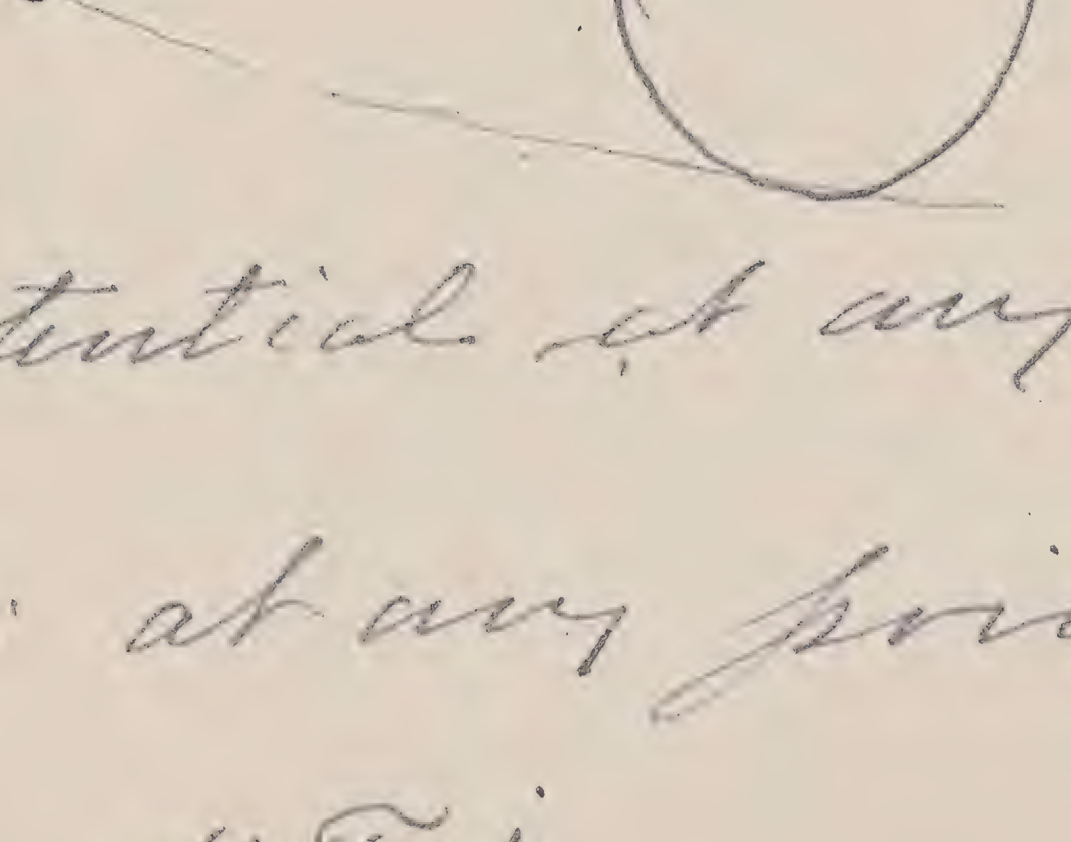
All points at wh. the surface subtends the same solid ∠s, have the same potential.

At a plane part of the surface the potential is $2\pi i$.



At mag. surface K, the potential changes by $4\pi i$

A closed shell.



potential at any point outside is 0: at any point inside $4\pi i$

It is an experimental fact that a circular current has the same effect as a small magnet whose axis is at rt. ∠ to plane of current.

An electric current flowing around the surface will exactly replace the equiv. magn. Can pass from the potential of a mag. shell to that of an electric circuit.

Potential is really.

$$V = 2\Omega + n4\pi i.$$

Unit current is a current wh. flowing around a shell of unit strength, will exactly replace such imag. shell -

In the case of an electric current we generally put

$$V = -i\Omega.$$

for a current flowing

the positive direction of potential is inward towards the paper

To calculate the potential energy of a system $\pm m$

shell

The amount of energy expended in bringing the pole up to point m. is

$$W = i\Omega m = E.$$

The number of lines of force going from the pole m. neglecting the effect of the shaft:- at unit distance from the pole the force is

$$\frac{m}{r}$$

and the total surface at this distance is 4π. ∴ the total no. of lines is

$$4\pi m.$$

The no. of lines included within a certain solid ∠ Ω is

$$m\Omega = N$$

And we may write for the energy of the system

$$\mathcal{E} = iN$$

For a number of mag. poles we have
$$\mathcal{E} = i \Sigma N.$$

Now suppose these points become a mag.

The actual energy of a mag. is that number of lines of force that would pass through the shell from the mag. if they were not deflected.

For two electric circuits we have:

$$-i'N = -iN'$$

To find the number N of lines of force due to a circuit

$$V = -i\Omega$$

$$F = -\frac{dV}{dr} = i\frac{d\Omega}{dr}$$

The number of unit tubes passing in a given surface is proportional to the strength of the current; that is

$$N = iM$$
$$N' = i'M'$$

Substituting above we find

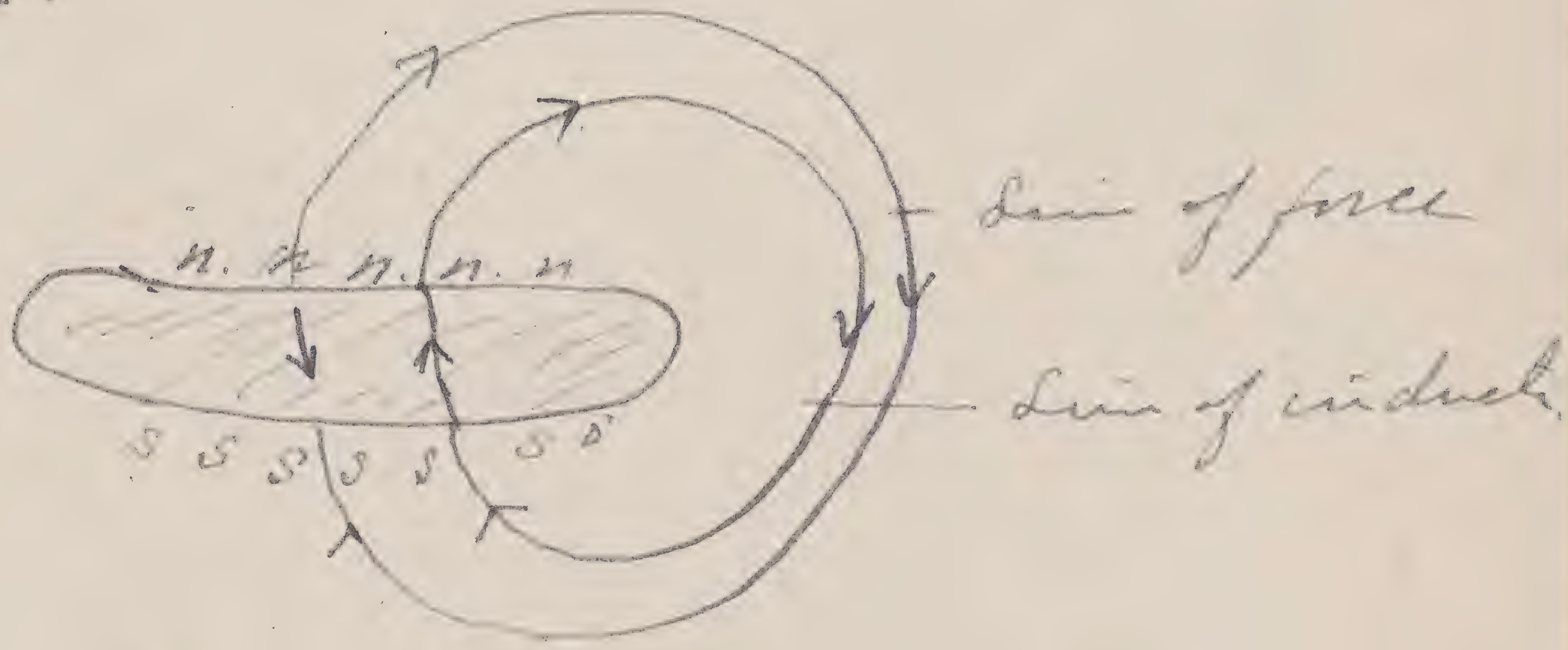
$$M = M'$$

M is purely a geometrical quantity and can be calculated

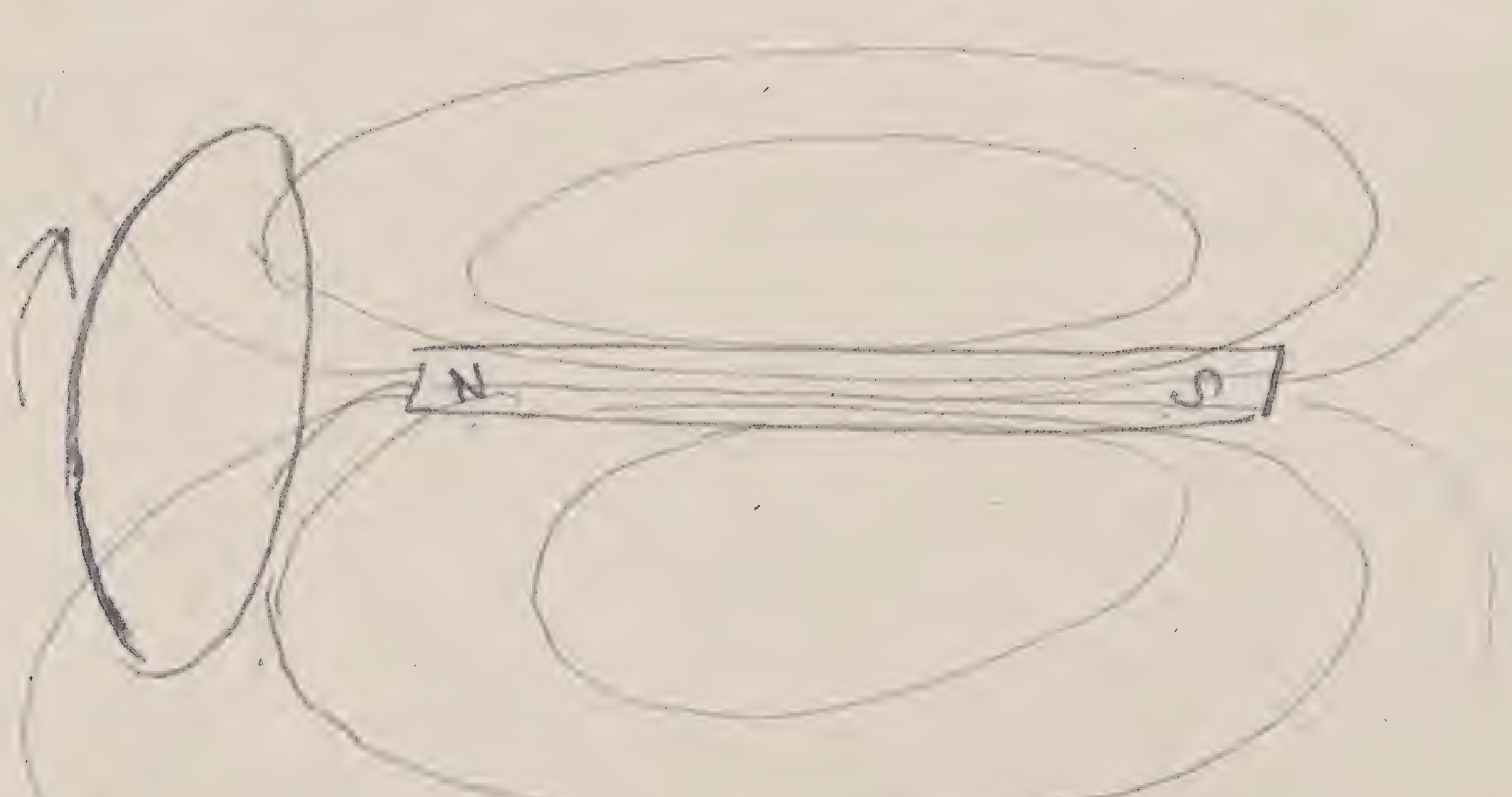
when we know the size etc. of the system. This quantity is called the coefficient of mutual induction.

What we have been calling lines of force are really lines of induction.

Lines of mag. induction are continuous. Lines of force change direction outside of the mag.



Take the system



The mutual energy is

$$-iM.$$

As the mutual energy tends to a minimum; that is tends to increase —; M will tend to increase, and the coil will tend to take up a stable position round the center of the magnet.

There is no tendency to move along a line of force; but to move so as to change the number of lines of force.

Intrinsic Energy.

The mutual energy due to the two circuits is

$M i_1 i_2$.

How can we express the energy in one system due to the current flowing in it.

Let the two systems coincide and we have a single current, and we can see thus, that the intrinsic energy is of the same form as above; that is the intrinsic energy is

$$L_1 i^2$$

where L_1 is a geometrical quantity: i the current. And the total energy of the system will be:

$$L_1 i_1^2 + L_2 i_2^2 + M i_1 i_2$$

And if we suppose the two currents to be equal and are made to coincide

Coeff. of self induction

Total energy of the system

$$L i^2 + M i i' + L' i'^2$$

Assume that the coils are equal and the same currents passing in each; then

$$L i^2 + M i^2 + L i^2$$

Now let the coils coincide any line of force originating in one will pass thro' the other; and thus becomes

$$M_0 i^2 + 2 L i^2 = 4 L i^2$$

$$\therefore \quad L = \frac{M_0}{2}$$

The coef. of self induction is one half the total number of lines of force when unit current passes thro' the circuit.

Establishment of a current

A battery is joined to a circuit wh. has no current.

R = resistance of the whole circuit.

E = electro-motive force

L = self induction.

The energy received from the battery in unit time will be

$$Ei.$$

the EMF times the current strength. In time dt.

$$Ei\,dt.$$

And this energy is expended in two ways. Part in heating the circuit, or frictional

sistance

$$R i^2 dt$$

and this part in increasing the no. of lines of force.

$$\frac{d(Li^2)}{dt} dt$$

whence

$$E i dt = R i^2 dt + \frac{d(Li^2)}{dt} dt$$

$$= R i^2 dt + 2Li \frac{di}{dt} dt$$

$\therefore$

$$\frac{di}{dt} + \frac{R}{2L} i = \frac{E}{2L}$$

integrating

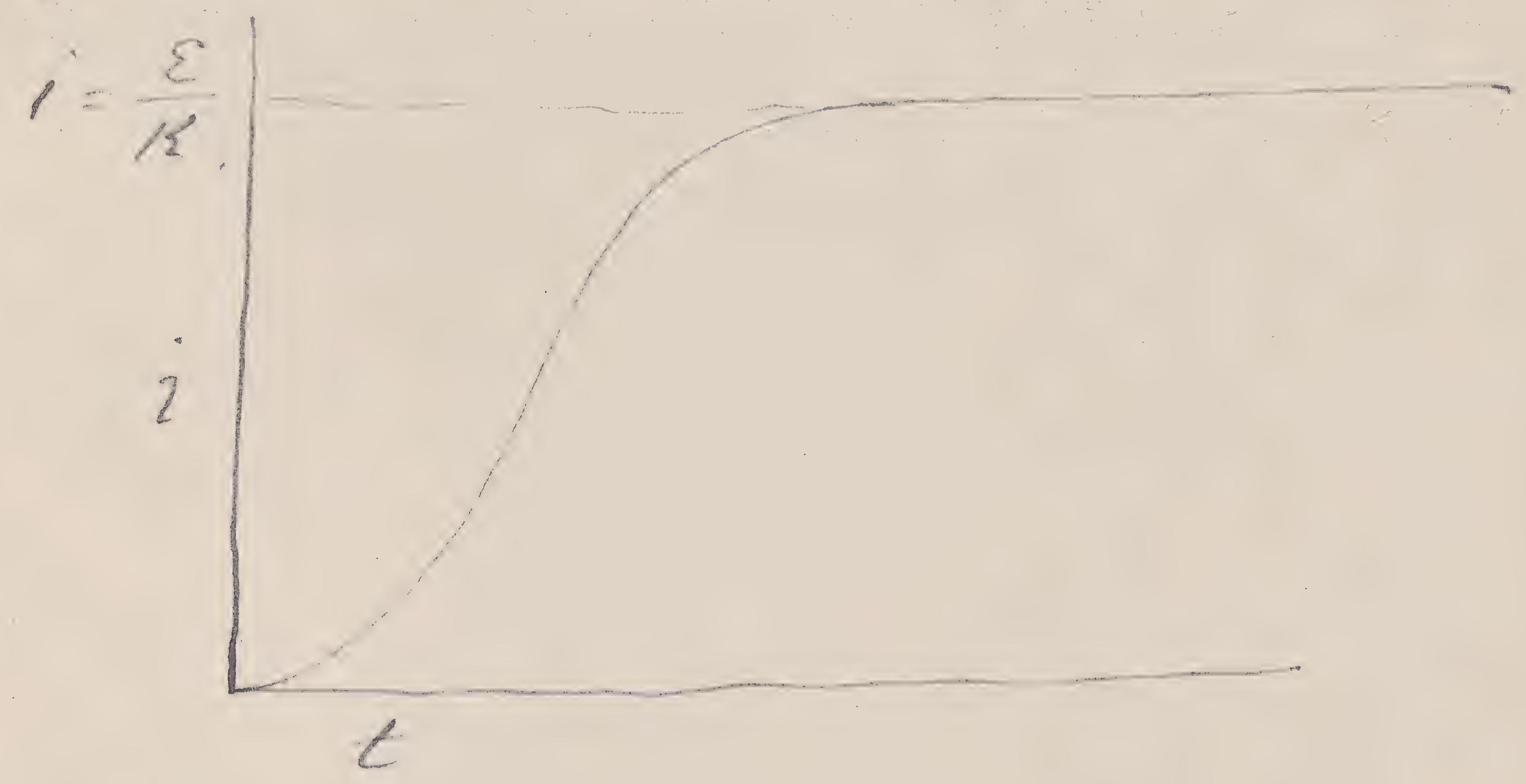
$$i = \frac{E}{R}\left(1 - e^{-\frac{Rt}{2L}}\right)$$

At the end of an infinite time, when the current has come to conditions of steady flow

$$i = \frac{E}{R}$$

wh. is Ohm's law.

The rise in current strength may be represented by the curve



The current reaches its max. in a very short time.

We have neglected the capacity of the system. In the case of an ocean cable the capacity is by far the most important item in the establishment of a current

Induction

Suppose we move a current of strength i with reference to a mag. field. In the first place the energy is

$$-iN$$

in the second position

$$-iN'$$

And the rate in wh. the pot. energy increases is

$$-i\frac{dN}{dt}.$$

Experiment shows that when the circuit is moved a current is set up.

The energy the circuit receives from the battery is $Ei\,dt$ and this is expended in overcoming resistance

$$Ei\,dt = Ri^2 dt$$

when in steady conditions.

If the circuit moves there is a diminution of pot. energy.

$$Ei\,dt = Ri^2 dt + i\frac{dM}{dt}dt$$

put $i_0 = \frac{E}{R}$

and we have

$$i_0 = i + \frac{1}{R}\frac{dM}{dt}$$

$$\therefore i - i_0 = -\frac{1}{R}\frac{dM}{dt} = \delta$$

the induced current wh. is equal to the diff. between the steady current and the

actual current at the time t.

$$x = -\frac{\frac{dN}{dt}}{R}.$$

the electro-motor force due to the induced current is

$$e = -\frac{dN}{dt}$$

$$\int x\,dt = Q$$

the total quantity of elec. in the induced current.

$$Q = -\frac{1}{R}\int \frac{dN}{dt}\,dt = -\frac{N' - N}{R}.$$

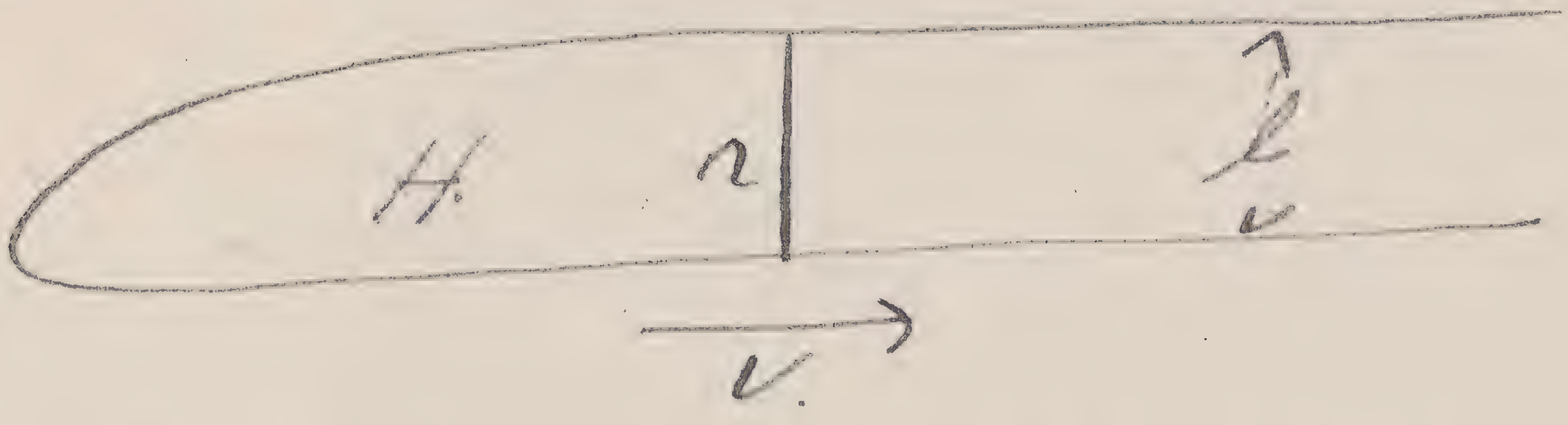
where N' and N are the no. of lines of force passing thro' the circuit at the beginning and end of the movement.

The formula for an induced current is

$$I = -\frac{1}{R}\cdot\frac{dN}{dt} = \frac{\mathcal{E}}{R}$$

where $\mathcal{E} \equiv -\frac{dN}{dt}$.

Suppose a conductor of the form.



lines of force are at rt ∠'s to the plane of the paper. The conductor r moves along the rails with a uniform velocity v. The no. of lines of force is thus increasing. In unit time r moves thro' a distance v, and the increase in area of the circuit is

vl.

and this multiplied by the no. of lines of unit area H, we have

$$\frac{dN}{dt} = vl.H = E$$

and the resistance is r. ∴

$$I = -\frac{vlH}{r}$$

If we have a circular circuit of area A revolving in a uniform field with H lines of force per unit area. By one revolution the change in no. of lines of force is

2 HAn.

$$\therefore -\frac{N'-N}{R} = -\frac{2HAn}{R} = Q$$

This gives the principle of the dynamo machine.

To determine the resistance in absolute measure. Lorenz's method.

Two coils placed ∥ to each other: when a current i flowing in the first and is suddenly reversed;

$$M = M_0 n_1 n_2$$

and the total no. of lines of force passing thro' the second coil is

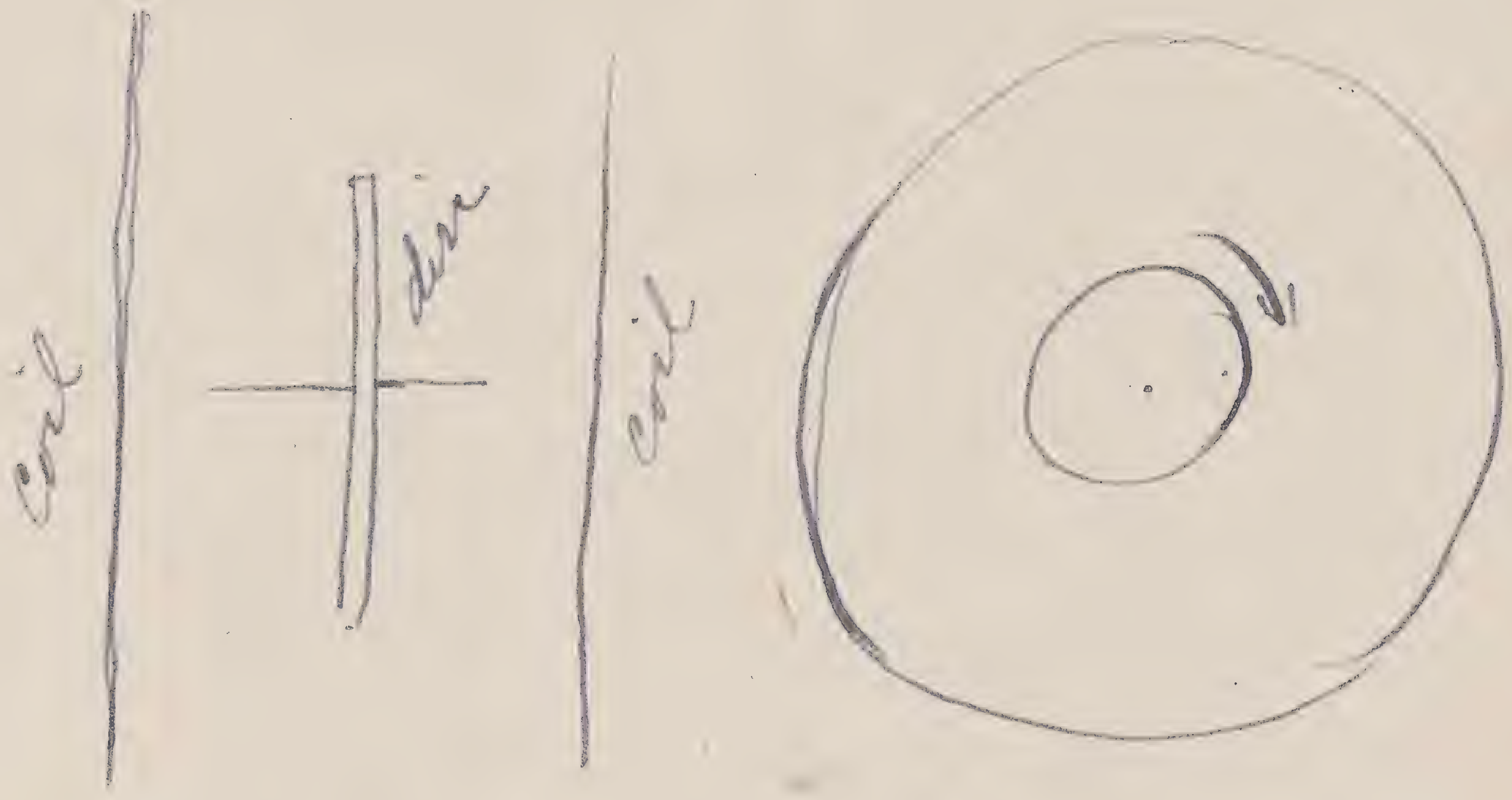
$$iM = iM_0 n_1 n_2$$

and by ~~the~~ reversal the total change is

$$2iM_0 n_1 n_2$$

$$\therefore Q = -\frac{2 i M_0 n_1 n_1}{R}$$

and by measuring i and Q we can find R.



A disc revolving between two coils, the lines of force will be $\perp$ to the plane of the disc.

The disc makes n turns per. sec.

M the coef. of mutual inductivy between the disc and the coils

i. the current in the coils.

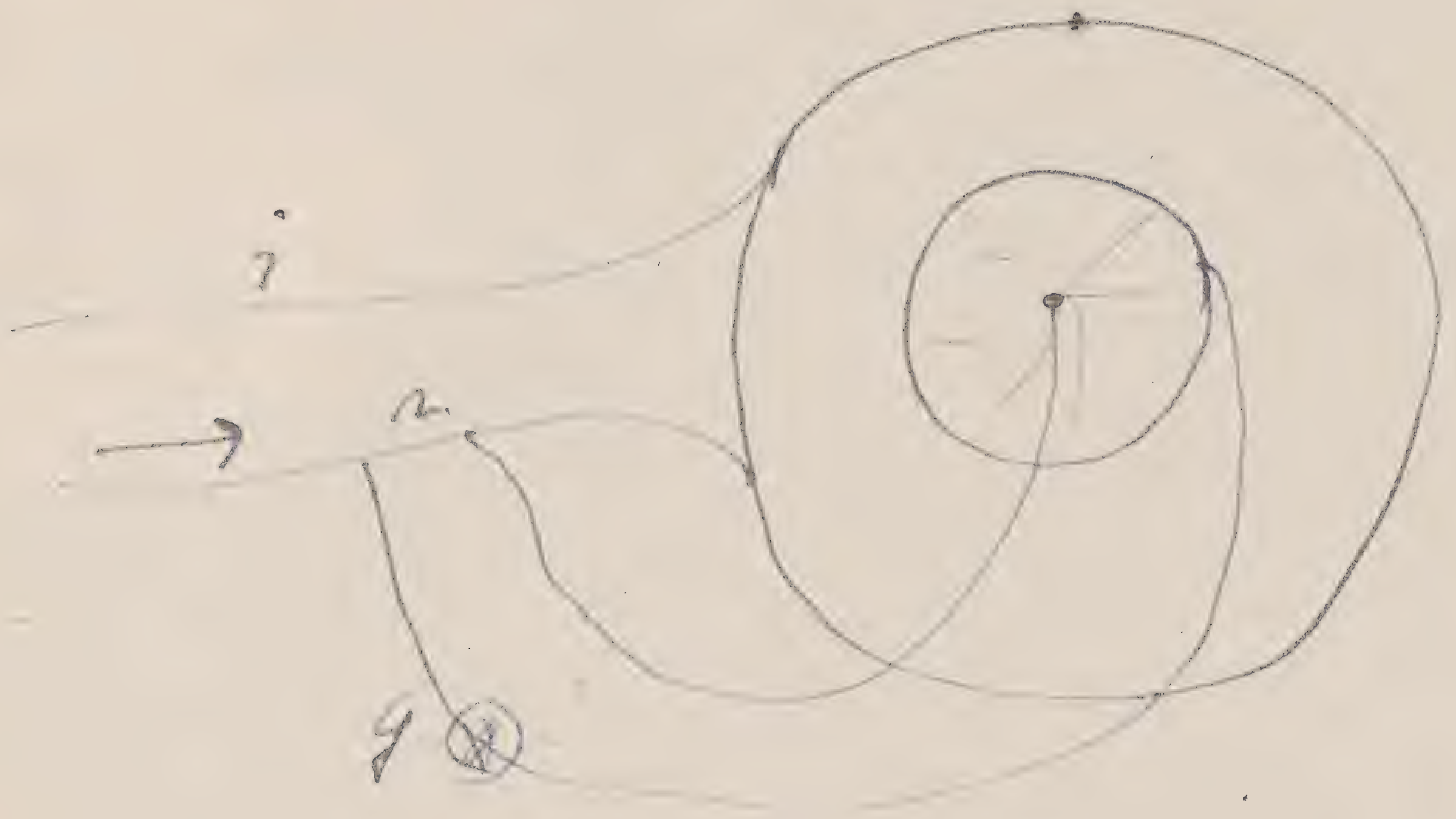
$\therefore i M n$

the no. of lines of force added

per sec. of one radius of the disc.

$$\therefore \quad X = -\frac{iMn}{R}$$

and $$iMn = \varepsilon$$



$$\varepsilon' = ir = iMn$$

$$\therefore r = Mn$$

In the case of an ordinary induction coil we can now see the reason for the high electro-motive force. Still depend upon the time of the contact being very small. The Foucault interrupter, mercury and alcohol.—

When iron is present the no. of lines of force is not proportional to the current strength

To determine the field of force due to a straight wire:

W = the wire ⊥ to plane of ink and as we must always think of a closed circuit we think of the wire forming a coil in the plane KW and extending to infinity

The solid ∠ Ω about p subtended by the circuit is

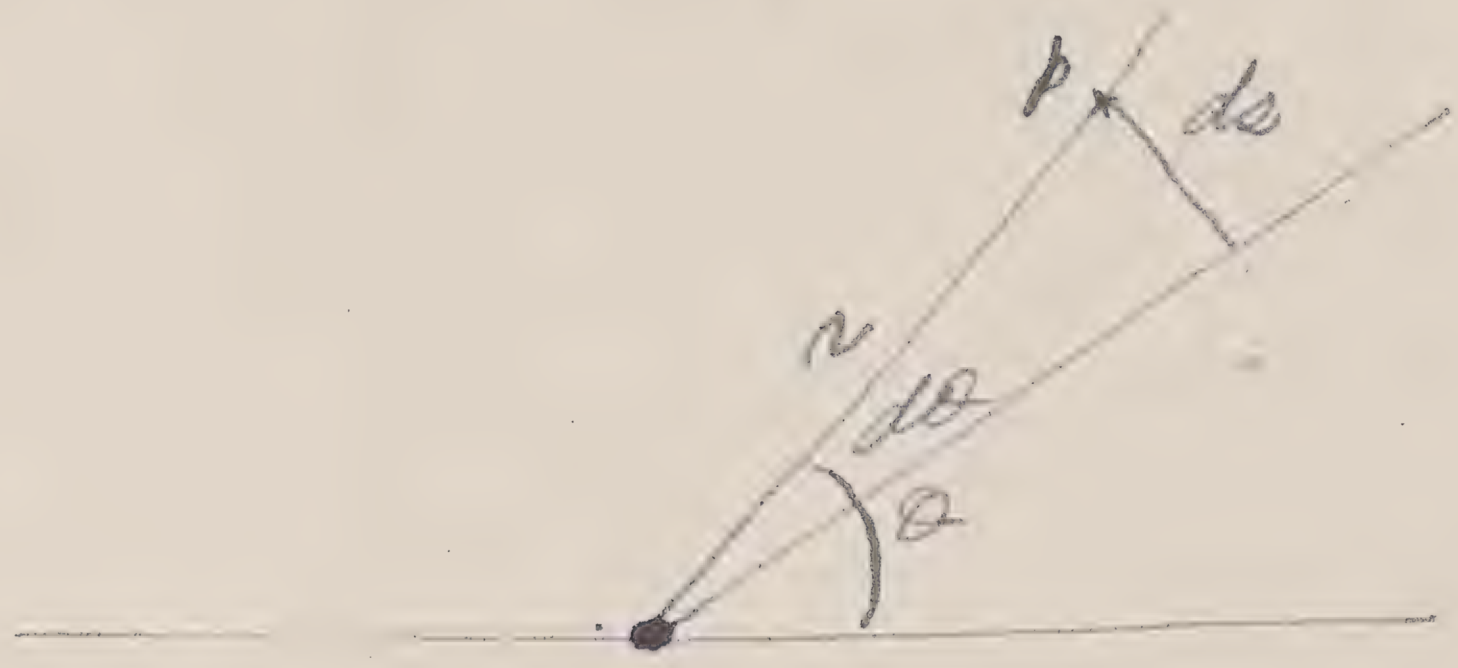
$$\frac{\Omega}{4\pi} = \frac{\theta}{2\pi}$$

$$\therefore \Omega = 2\theta = 2\theta$$

and the potential at p is

$$V = -i\Omega = -2\theta i$$

The equipotential surfaces are then planes passing through the wire, and the lines of force circles around the wire.



To find the force:

$$F = -\frac{dV}{ds}.$$

$$ds = r\,d\theta$$

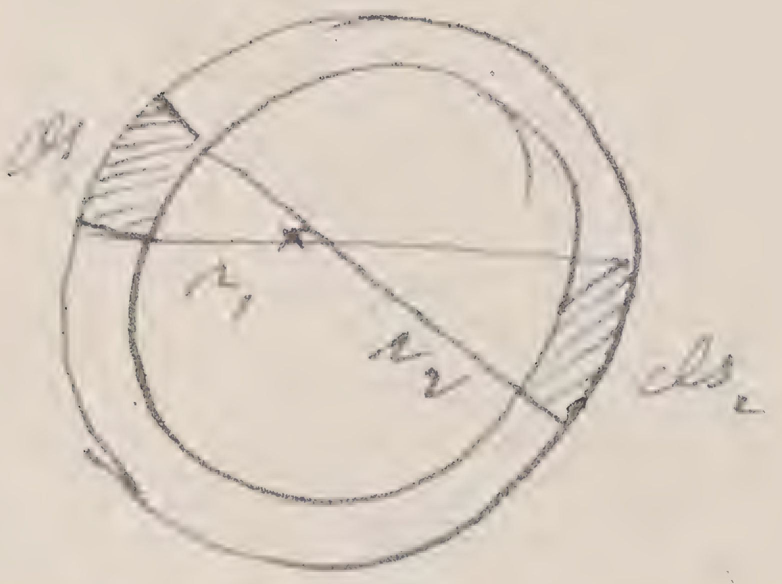
$$F = -\frac{1}{r}\frac{dV}{d\theta}$$

but $dV = -2i\,d\theta$ $\therefore \frac{dV}{d\theta} = -2i.$

$$F = \frac{2i}{r}$$

The force at the center of the wire is then infinite. We must study then what takes place within the wire.

Consider the wire as a shell.



ρ = density of current.

$i = \rho ds$

is the current in the element

$$\frac{2\rho\, ds_1}{r_1} = \frac{2\rho\, ds_2}{r_2}$$

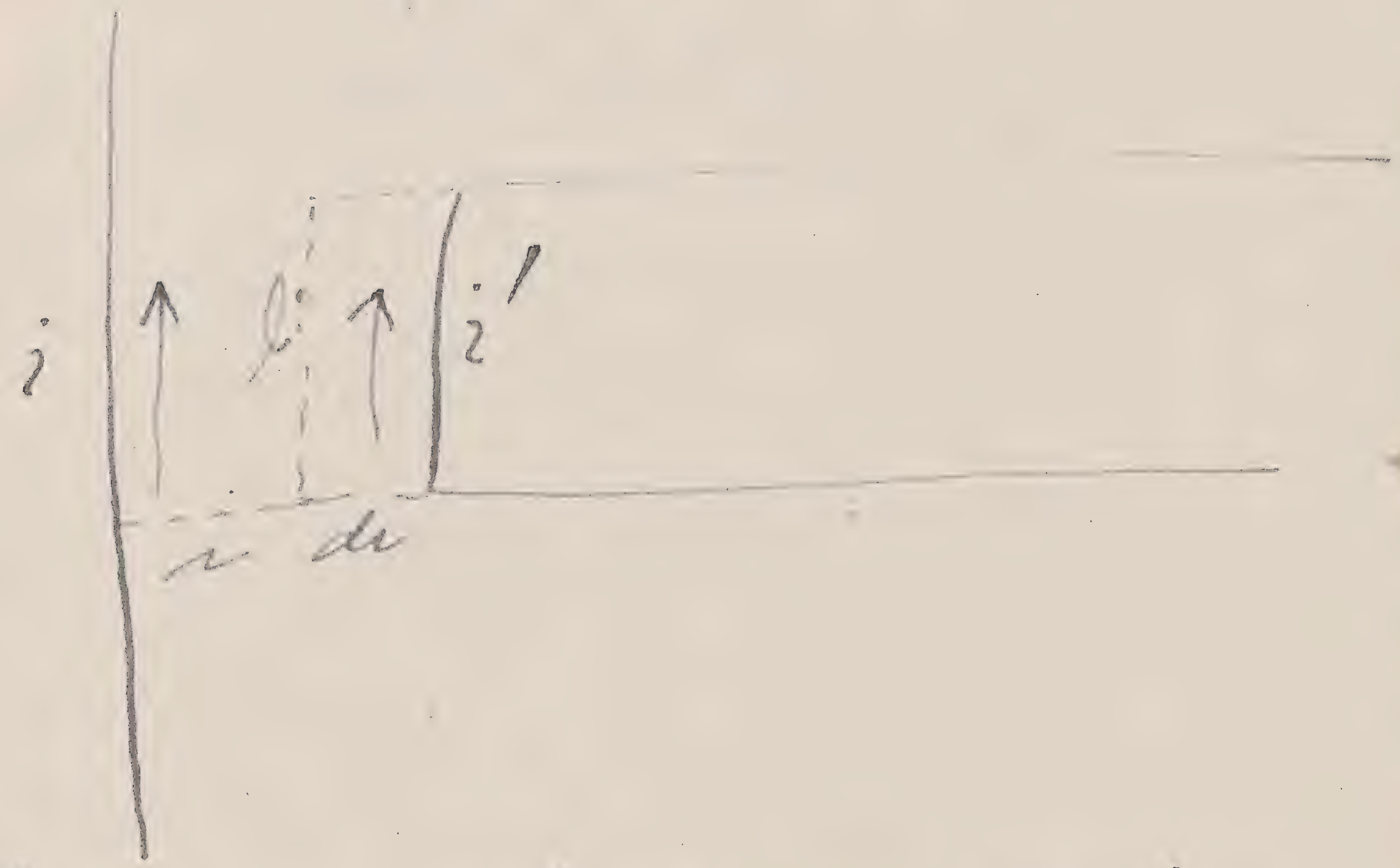
Such a current shell produces zero magnetic force on any point in the interior. So that the effect on any point in a wire is due only to that part of the wire nearer the center of the wire than the point.

At the surface the max. value of the force is

$$\frac{2I}{R}$$

and it constantly diminishes towards the center.

If we have the following system to find the attraction.



Suppose the circuit i' is moved up thus the distance dr. The intensity of the field is

$$\frac{2i}{r}$$

and the area passed over will be

$$l\,dr$$

and the change in the no. of lines of force is

$$\frac{2i}{r}\,l\,dr.$$

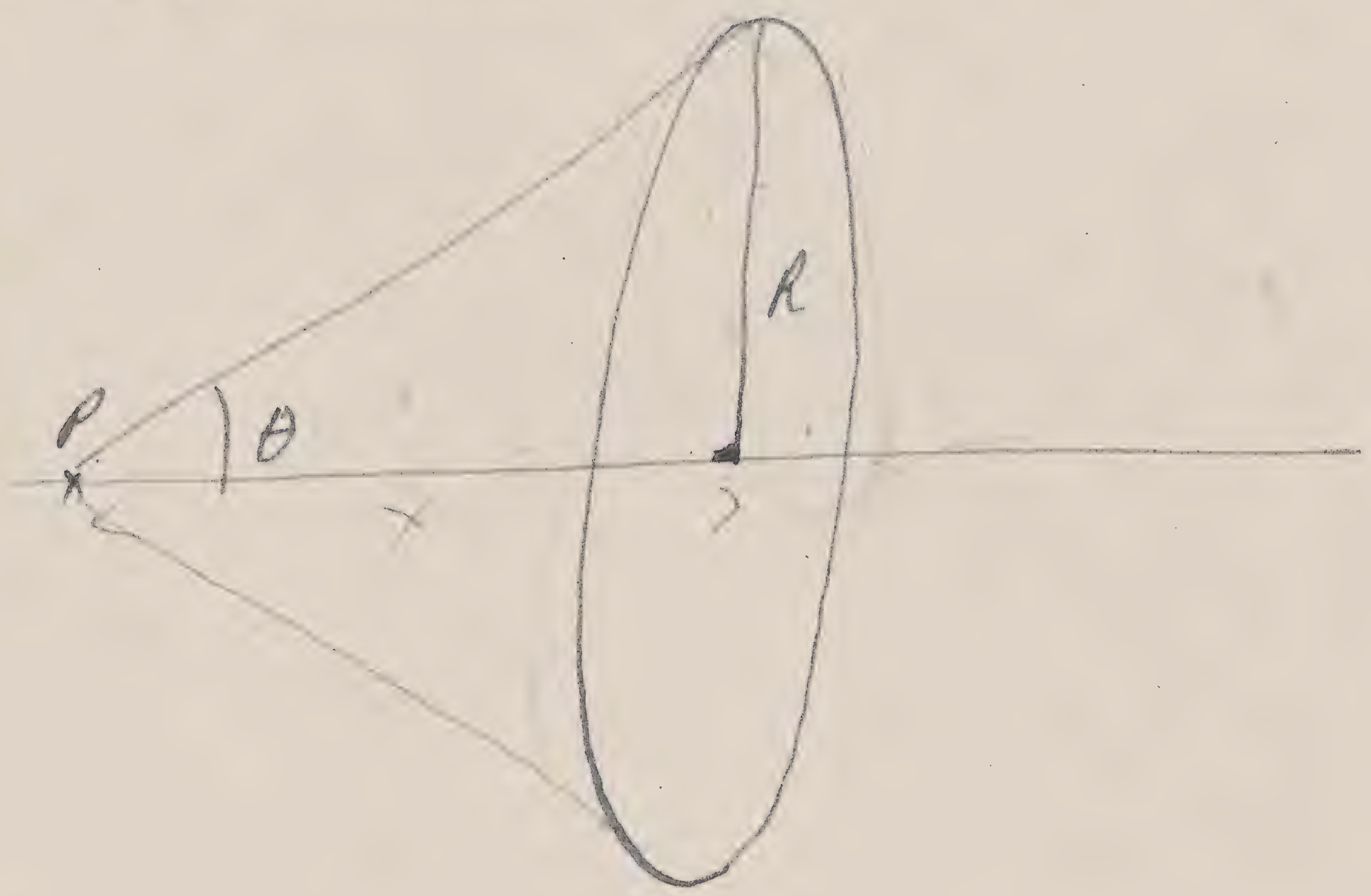
and the change in the energy is

$$dE = \frac{2ii'}{r}\,l\,dr.$$

and so the attraction is

$$\frac{dE}{dr} = \frac{2ii'}{r}\,.\,l.$$

The field of force at the center of a circular current.



The potential at P is

$$V = -i\Omega$$

but for the value of Ω we have

$$\frac{\Omega}{4\pi} = \frac{1-\cos\theta}{2}$$

$$\therefore \Omega = 2\pi(1-\cos\theta)$$

$$\therefore V = -2\pi i(1-\cos\theta).$$

but $\cos\theta = \frac{x}{\sqrt{x^2+R^2}}$

$$V = -2\pi i\left(1-\frac{x}{\sqrt{x^2+R^2}}\right)$$

and to find the force at p.

$$F = -\frac{dV}{dx}$$

$$= 2\pi i \frac{R^2}{(x^2+R^2)^{3/2}}$$

and making x equal 0 we get the force at the center.

$$F = \frac{2\pi i}{R}_{x=0}$$

Field of force within a long helix.

Each turn is equiv. to a mag. shell, of strength i. In going from one side of such a shell to the other there is a change of potential of

$$4\pi i.$$

The total change in potential per unit of length, n turns per unit of length, is

$$4\pi i n$$

but this is the force.

$$\frac{dV}{dx} = 4\pi i n$$

and this force does not depend upon the position

of the point in the helix, i. e.,
whether in the axis or not.

In all this we have neglect the effect of the ends.

The force just outside the helix will be zero.

A ring mag. may be made in this way.

To find the effect of iron in such a ring. The iron sets up a great many more lines of force. The total no. now being
$$4\pi i n \mu.$$
To investigate this place another coil around the first and connect with a gal.

$$Q = -\frac{N'-N}{R} = \frac{8\pi i n}{R}\mu$$

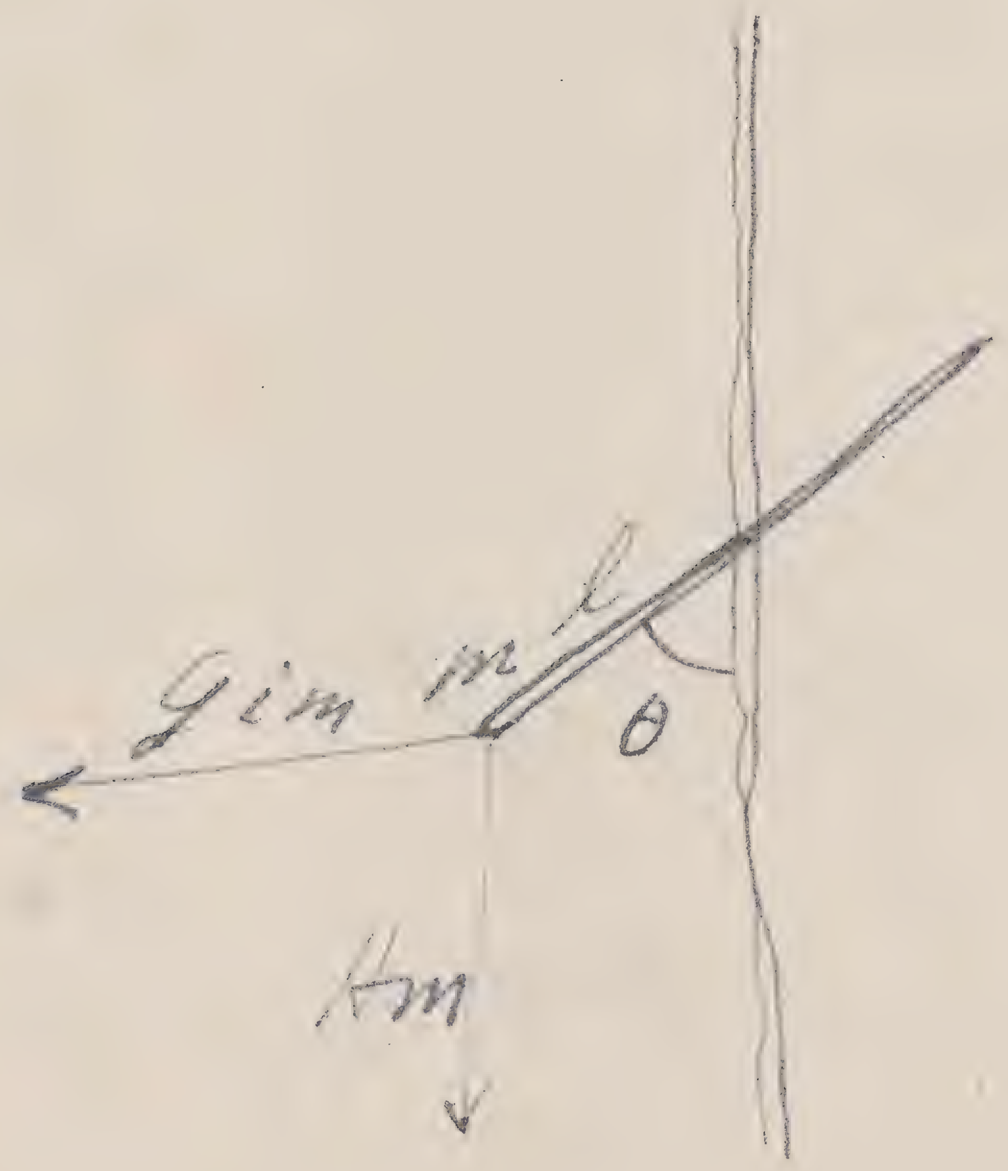
Q the induced current in the second coil. In this way can find the value of μ.

Measurement of Currents

We have seen how to calculate the field of force due to a coil at a point on its axis.

The field of force due to unit current at the point where the needle is placed is G, the gal. constant

$$G = \frac{2\pi n}{r}$$



The force due to coil tending to deflect the needle is

$$Gim$$

and the force due to earth's mag. is

$$Hm.$$

We have.

$$Hml \sin \theta = Giml \cos \theta$$

$$i = \frac{H}{G} \tan. \theta$$

The strength of the mag. does not enter this formula; but we should always use a strong one in order to overcome friction of pivot etc.

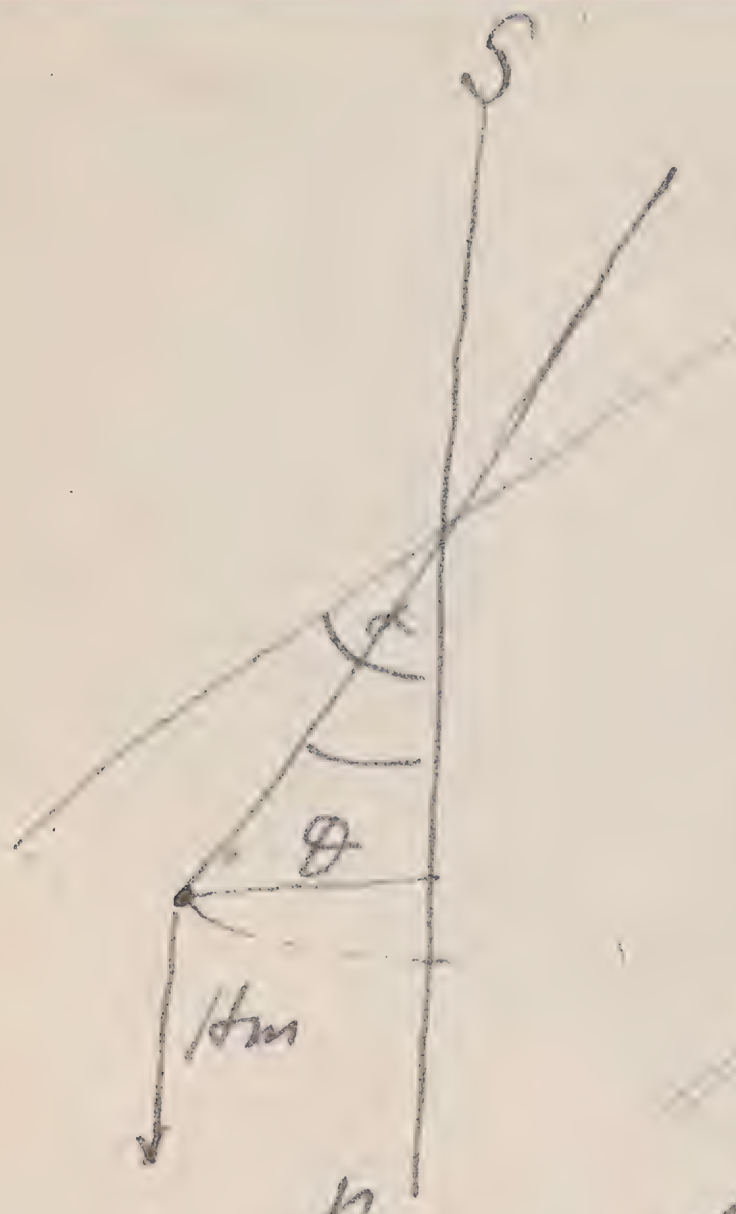
In this formula G. was calculated for the centre of the coil, but the pole

is not in the center ∴ we have a correction due to the length of the needle. The needle should be very short as regards the diameter of the coil.

This is the ordinary tangent gal.

In Helmholtz's gal.

the field is made uniform and the correction for the needles length is not so important.



How much work will have to be done to turn the mag. from its zero position thro' the $\angle \theta$. The force tending to replace it is Hm and the mag has moved against this force a distance of

$$l(1-\cos\theta)$$

and the work done is

$$Hm\,2l(1-\cos\theta)$$

and as this will be the kinetic energy when the mag. reaches the zero point we is moving

$$\therefore \quad Hm\,2l(1-\cos\theta) = \tfrac{1}{2}K\omega^2$$

when ω = angular velocity.

K = moment of inertia

but.

$$1 - \cos\theta = 2\sin^2 \tfrac{1}{2}\theta.$$

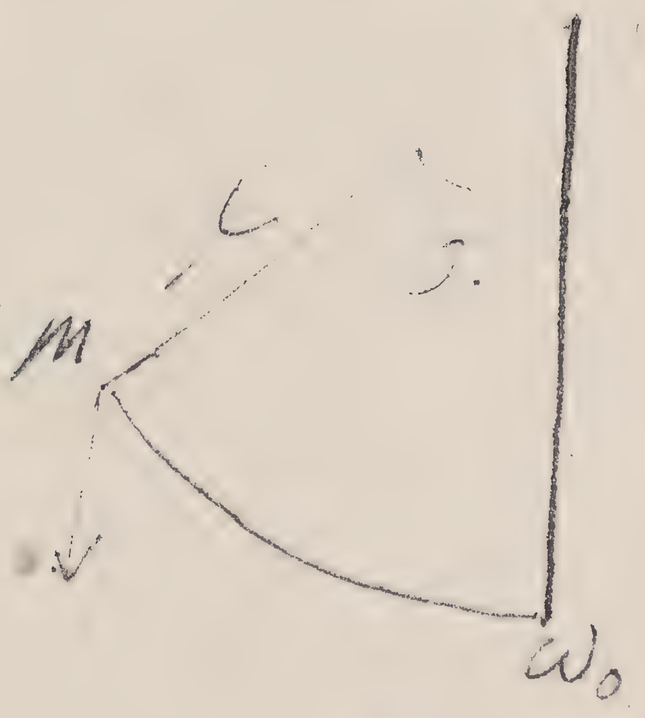
we have then. putting

$$m2l = M.$$

$$HM \cdot 4\sin^2\frac{\theta}{2} = K\omega_0^2$$

$$\omega_0 = 2\sin\frac{\theta}{2}\sqrt{\frac{HM}{K}}$$

To measure a transient current we must know the period of swing of the mag



the work done in moving the mag from ω_0 to m is

$$H2ml(1-\cos\theta)$$

$\therefore \quad HM(1-\cos\theta) = \frac{1}{2}K(\omega_0^2 - \omega^2)$

and if α is the extreme $\angle$ of elongation

$$HM(1-\cos\alpha) = \frac{1}{2}K\omega_0^2$$

subtracting

$$\frac{1}{2}K\omega^2 = HM(\cos\theta - \cos\alpha)$$

developing

$$\cos\alpha = 1 - \frac{\alpha^2}{2} + \text{etc.}$$

$$\therefore \frac{1}{2}K\omega^2 = HM\frac{1}{2}(\alpha^2 - \theta^2)$$

but ω^2 is the sq. of ang. velocity

$$K\left(\frac{d\theta}{dt}\right)^2 = HM(\alpha^2 - \theta^2)$$

$$\frac{d\theta}{\sqrt{\alpha^2 - \theta^2}} = \sqrt{\frac{HM}{K}}\,dt$$

integrating between limits $\theta = 0$, $\theta = \alpha$ wh. is 1/4 of a complete oscillation.

$$\int_0^{\alpha} \frac{d\theta}{\sqrt{\alpha^2 - \theta^2}} = \frac{T}{4}\sqrt{\frac{HM}{K}}$$

integrating

$$\frac{T}{4}\sqrt{\frac{HM}{K}} = \frac{\pi}{2}$$

$$T = 2\pi\sqrt{\frac{K}{HM}}$$

and this corresponds to the ordinary formula for the pendulum.

$$T = 2\pi\sqrt{\frac{l}{g}}$$

$$= 2\pi\sqrt{\frac{l^2 m}{gml}}$$

for $gml = HM$, and $l^2 m = K$.

To find relation between flux of mag. and current.

The impulse given the needle by the current is

$$\mathcal{L} = \int i\, G m\, 2l\, dt$$

$$= QGM$$

$$= K\omega_0$$

where ω_0 is the $\angle$ velocity at the lowest point, and from this can find Q. We have

$$\omega_0 = 2 \sin\frac{\alpha}{2}\sqrt{\frac{HM}{K}}$$

$$Q = \frac{K}{GM}\, 2 \sin\frac{\alpha}{2}\sqrt{\frac{HM}{K}}$$

The quantities $\frac{HM}{K}$ are difficult determine, so if possible

get rid of them, we have

$$T = 2\pi\sqrt{\frac{K}{Hm}}$$

substituting we have

$$Q = \frac{TH}{g\pi}\sin\frac{\alpha}{2}$$

We have had electro-static units; in rob. we find dam

$$F = \frac{qq'}{r^2}$$

in this system we defined strength of mag. pole.

$$F = \frac{mm'}{r^2}$$

and now we have defined

current strength, either as electro-static units or as electro-mag.—

$$f = \frac{2\pi i}{R}.$$

We can measure the quantity of elec. either way we choose. In order to compare the units we must take the same thing and measure it in two different ways.
In the electro-static system the quantity is known when we know capacity and potential

$$Q = CV.$$

We find it this way with a spherical condenser.

Discharge the condenser

tan. gal. and find

$$Q' = \frac{HT}{\pi G} \sin\frac{\alpha}{2}$$

and we have measured the same quantity of elec. in two different ways.

$$\frac{Q}{Q'} = 30,000,000,000.$$

In the electro-static system

$$F = \frac{QQ'}{r^2}, \quad Q^2 = FL^2$$

but dimensions of $F = \frac{ML}{T^2}$

$$\therefore Q^2 = \frac{ML^3}{T^2}$$

and the dimensions of Q in this system

$$Q = M^{1/2} L^{3/2} T^{-1}$$

In the electro-mag. system, the dimensions

of m, the strength of mag. pole are same as Q in statics

$$m = M^{1/2} L^{3/2} T^{-1}$$

and force

$$F = mi \frac{d\alpha}{dr} = \frac{mi}{L}$$

i.e. current strength = quantity divided by time.

$$F = \frac{m Q'}{L T} \therefore Q' = \frac{F L T}{m}$$

and substituting for m its dimensions

$$Q' = M^{1/2} L^{1/2}$$

and for the ratio

$$\frac{Q}{Q'} = \frac{M^{1/2} L^{3/2} T^{-1}}{M^{1/2} L^{1/2}} = \frac{L}{T}.$$

and the ratio has the dimensions of velocity.

Our unit of length is the cm. and this ratio is the velocity of light. A wave of mag. induction will be propagated with this velocity in the ether.

Units, now in use belong to an electro-mag. system but not to the absolute system wh. we have been discussing. The absolute system is inconvenient for ordinary use the unit of length is

L 10^{9} cm.

M 10^{-11} gm.

T. second.

In this system, the units are

Ampère = Current

Volt = E.M.F.

Ohm = resistance

Coulomb = quantity

Farad = capacity

Watt, amount of energy expended by a current of one Ampère flowing with a E.M.F. of one volt.

These units are compared with the C.G.S. units

	C.G.S.
Ampère	= 10^{-1}
Volt	= 10^{8}
Ohm	= 10^{9}
Coulomb	10^{-1}
Farad	10^{-9}

In all these expressions, K, or μ should enter, but we don't know the dimensions of either: we know that

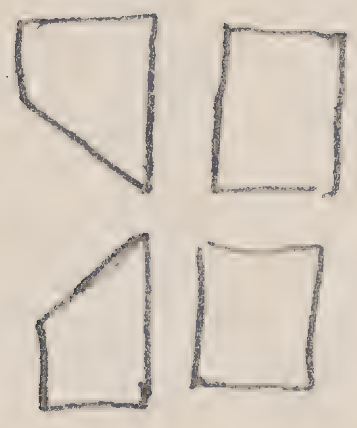
$$\sqrt{K\mu}$$

is of the dimensions of velocity.

Sensitive galv—

We have seen that conditions exist for length of needle etc. Also for cross section of coil, the ratios is something like 100:108. When we come to a sensitive gal. the problem is a difficult one. The best form of coil for this

purpose is of the form

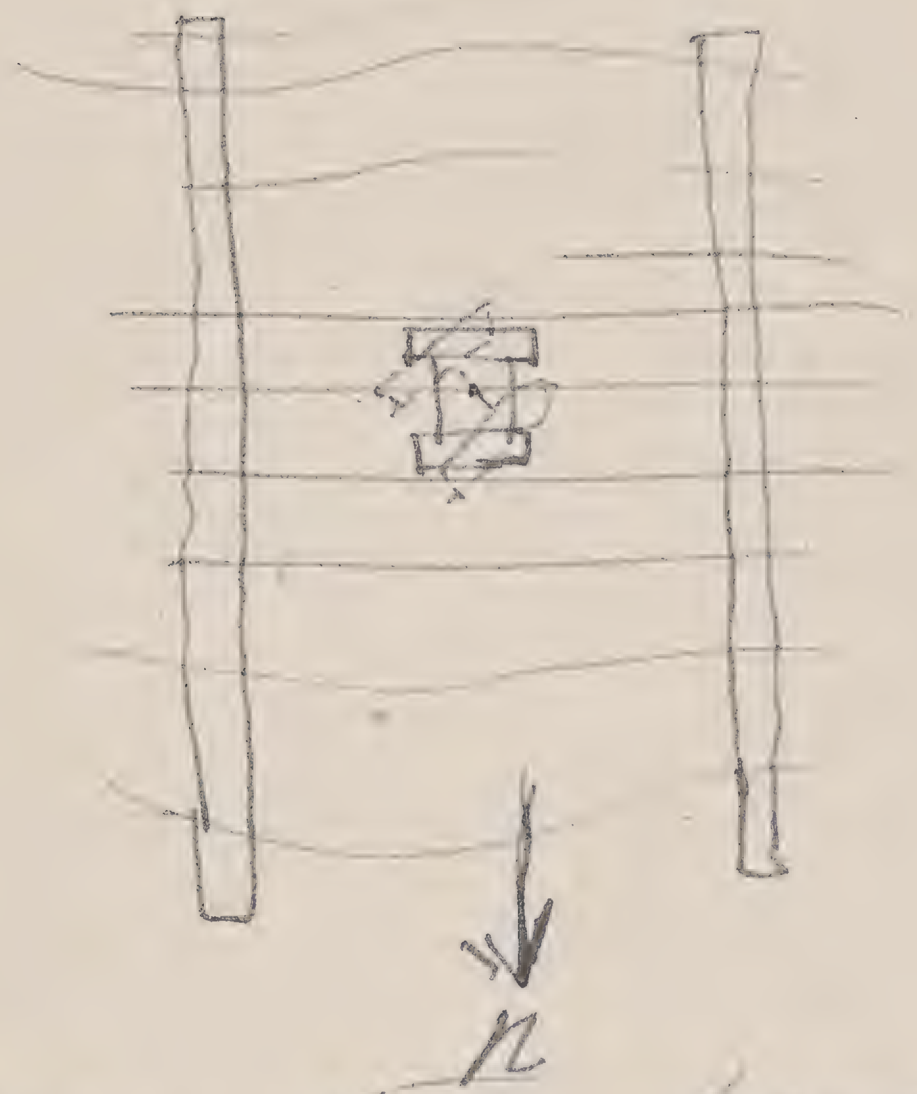


wind near the center with small wire and increase the size of the wire as you go out.

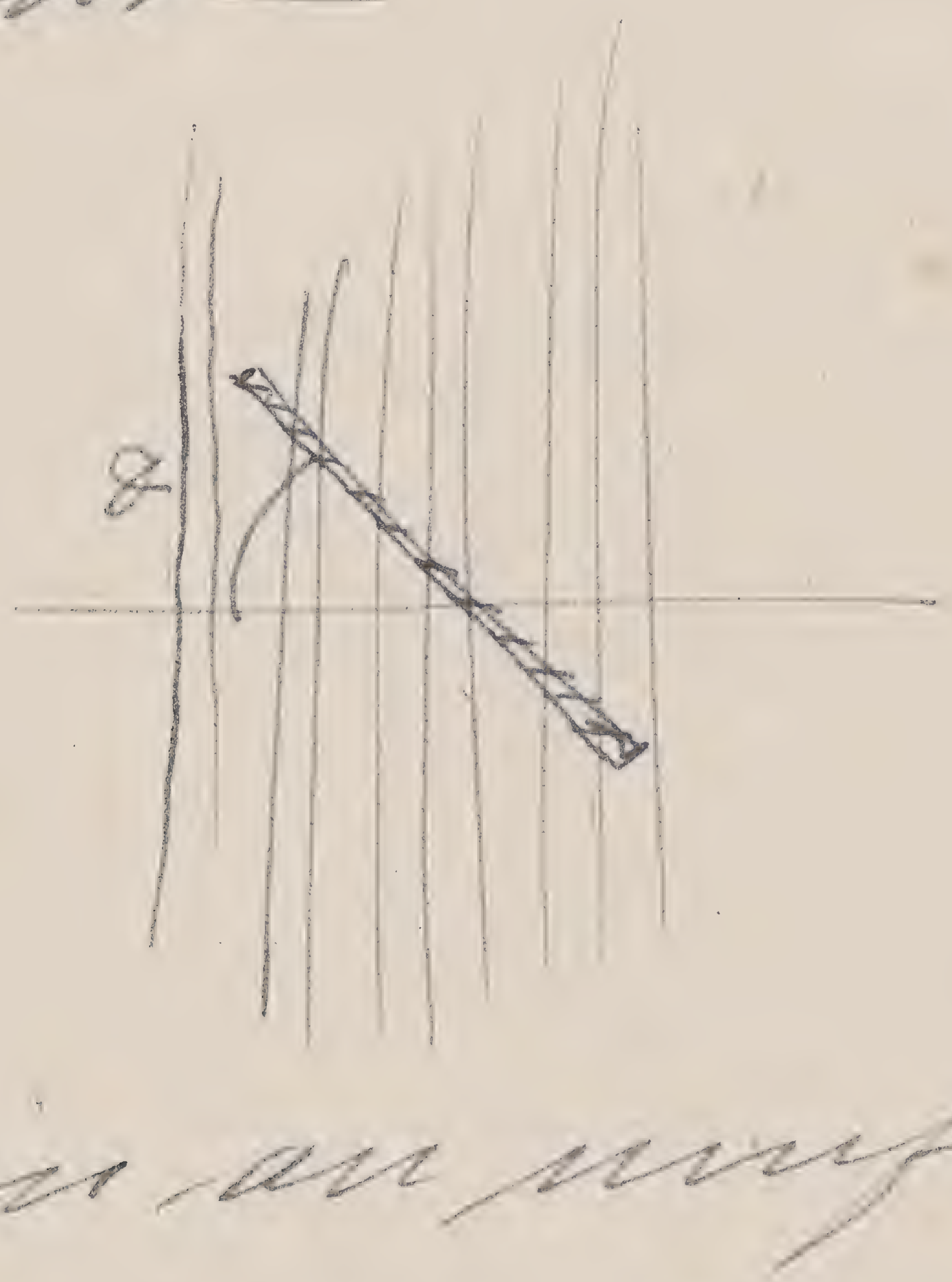
Must make the system independent of the earth's field; i.e. make the system absolutely astatic.

The electro-dynamometer to measure current independent of earth's mag. — Two small central coils are suspended with the outer coils, and a current passed through

tends to twist them and by measuring the torsion we have a measure of the current



A horizontal projection of the instrument—



A coil in an uniform field of force. Call the effective area of the single turn A, and the number of turns n,

HAn

will be no. of lines of force running thro' when in zero position. When turned by angle θ.

$HAn \cos\theta$

The current in it is i.

$$E = i\,HAn\cos\theta$$

To find the force

$$\frac{dE}{d\theta} = -\,i\,HAn\sin\theta$$

wh. is due to earth –

And the force due to the outer coils as

$$Gi^2 An\cos\theta$$

and the total force tending to turn the moving system

is equal to the external force and we have

$$iHAn\sin\theta + Gi^2An\cos\theta - F\sin\theta = 0$$

Now if the current be reversed the second term will not change its sign and we have

$$-iHAn\sin\theta' + Gi^2An\cos\theta' - F\sin\theta' = 0$$

By making two such readings we can get two equations, eliminate H, and find i.

The effect of introducing iron into a coil of wire.

Suppose we have a bar mag. with a small hole running thro' it. The mag. distributed on the ends only.

The resultant force on a particle in the interior is known as the mag. force.

Again suppose the particle to be put in a disc like opening at right <s to the lines of induction. It is acted upon by the sides of this disc as well as the ends of the mag. This resultant is called the

mag. induction.

$$\beta = H + 4\pi J.$$

mag. induction does not change its sign when the particle passes outside of the mag. as does the mag. force. Induction is continuous while force is not.

Let us now have a short mag. and mag. it by a solenoid

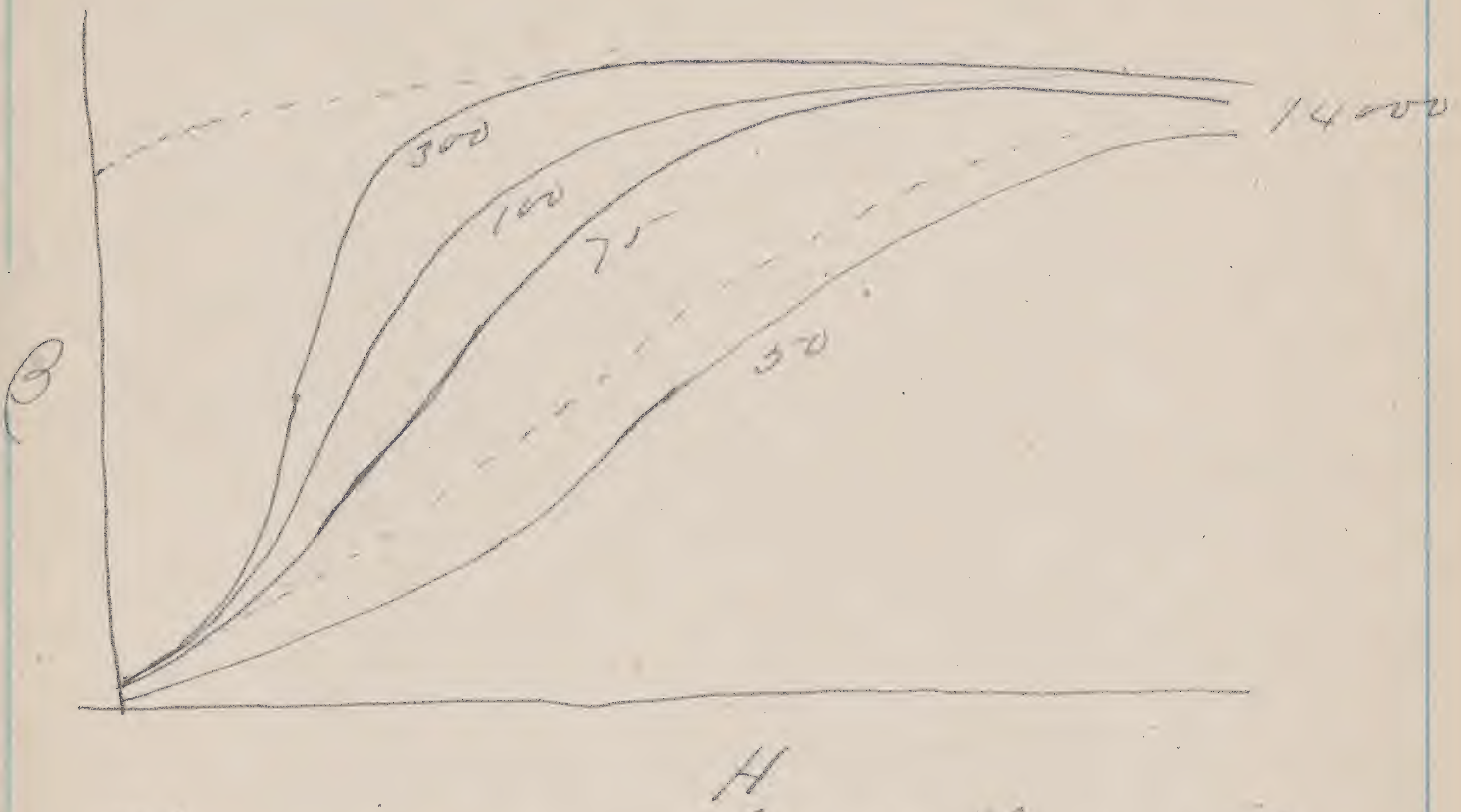
The influence of the ends tend to demagnetize the mag. they oppose the effect due to the coil. A long mag. is more

permanent than a short one-

Suppose we have a tube of force

and replace it, or fill it up, with iron: it would have no effect on the outside lines of force; but a larger no. of tubes of induction would pass thro' the iron, than thro' the air.

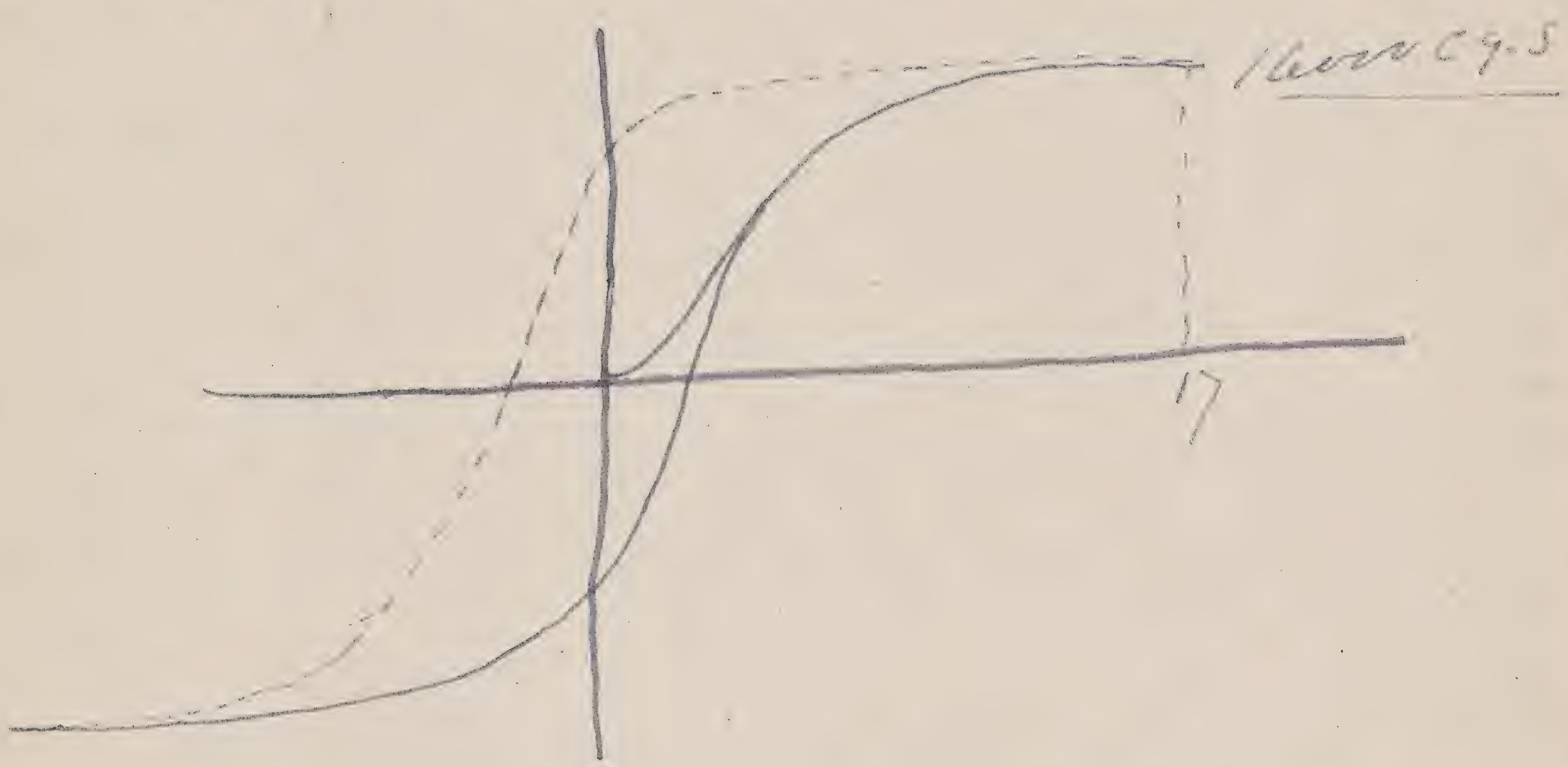
Ewing's experiments, found the following curves.



The wires in the solenoid were 50, 75, 100, 300 times as long as thick. The thick lines represent the increase in mag. the dotted lines the decrease, when current is decreased. When 300 times as long, the wires act like a ring, or closed solenoid, the ends have no effect. When only 50 times as long

the demag. force due to the ends; demag. it —

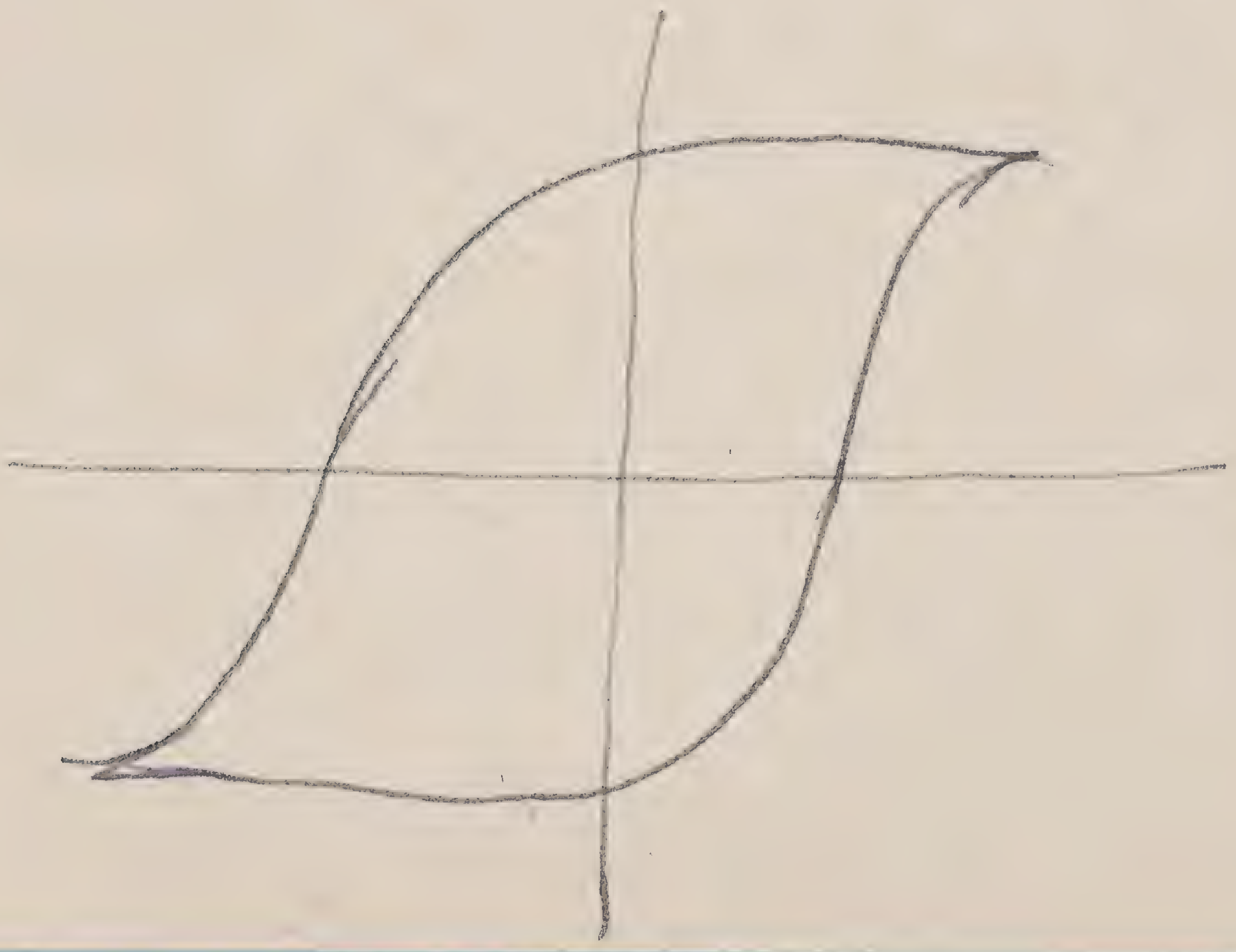
For a soft iron wire 400 times its diameter



abscissae are mag. force
ordinates " " induction

And in this diagram areas will represent work —

for glass hard steel the curve is



Mag. permeability = $\frac{B}{H} = \mu$
the ratio of the mag. induction
to the mag. force –

The rate of increase of lines
of force with force is a
different quantity = $\frac{dB}{dH}$

Mag. perm. depends upon
the past history of the system.

Can never bring a piece of
iron back to same condition
from wh. we started.

In the case of an ordinary induction coil, the rods are so short, that the demag. force is very great—

In an induction coil the quantity depends only upon the total change of lines of force and will be the same in breaking and making contact— The E.M.F is greater when breaking however—

Dynamos

$$E = -\frac{dN}{dt}$$

Hence to get a high E.M.F for a dynamo the field must be strong; large no. of turns; velocity of revolution must be great—

To get a large current, the

resistance must be small —

Since the field is excited by permanent mag., called mag-machines, or by electro-mag's — called dynamo, which may be self exciting or separate.

Magneto

Dynamo

Separate

Self-ex. { Series
Shunt —

The current flows from the armature around the field mags. then thro' the outer circuit and back to the armature - this is the series form -

If the field mags are connected with the poles of the armature, so that part of the current flows around the mags. and part thro' the external resistance - this is the shunt form -

In charging a storage battery we must use a shunt machine, for in the other case we might have reversal of current -

In the shunt machine, when the external resistance is ∞ we have max. E.M.F at the terminals — In the series form, when the resist is 0 we have max. current — By a combination of the two forms we may make a constant machine, one independent of the outside resistance. We may have either constant current or constant potential. In this combination the mag. is not carried to saturation

When the current passes in the armature, the lines of force are changed and become curved. and the brushes should be turned till they coincide with these lines.

The Gramme ring

The windings are a continuous helix around the ring. at certain points it is connected with the armature. The currents will be induced in opposite directions; ∴ the two points will be o points

of high potential and upper, a point of low potential; at these points then the brushes are placed.

If the ring were made of wood, instead of iron, we would get little or no current — the lines on the interior are more than useless; they introduce more resistance and also cut the lines of force in the wrong direction.

The ring is made of a bundle of wires; for if it were solid, the current would be induced around it.

In the case of an armature revolving between two poles it is found that the leaving pole becomes the hotter. This is due to the induced lines of force.

The total elec. energy developed by a dynamo is

$$CE.$$

the energy spent in any portion of the circuit is

$$C^2R$$

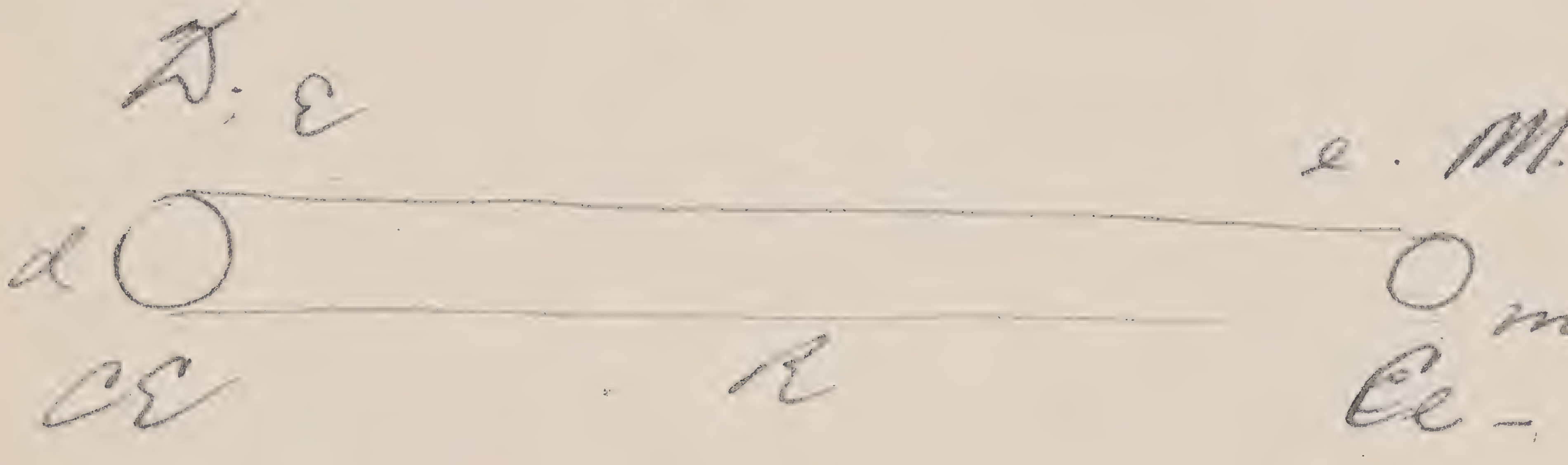
and if R is the resistance of the machine then the available energy is

$$CE - C^2R$$

and the efficiency is

$$\frac{CE - C^2R}{CE}.$$

All these instruments are in a certain sense reversible. By passing a current thro' we develope heat, or work. When a dynamo drives an another, as a motor, the current strength diminishes. The very fact that we get work here energy must be expended in the circuit. This should have been expected.



The case of a dynamo driving a motor M. The total resistance is $d + R + m$. The whole current is

$$C = \frac{E - e}{d + R + m} = \frac{E - e}{R'}$$

The current decreases as the counter elec motor force e, of the motor rise, and thus varies as the motor goes faster and faster —

$$\mathcal{E}_d = \frac{\mathcal{E}(\mathcal{E}-e)}{R'}$$

$$\mathcal{E}_m = \frac{e(\mathcal{E}-e)}{R'}$$

the energy absorbed respectively in the dynamo and motor.

$$\mathcal{E}_d - \mathcal{E}_m = C^2R' = \frac{(\mathcal{E}-e)^2}{R'}$$

the energy spent in overcoming frictional resistance — The efficiency is the ratio of the energy given out by the motor to that expended by the dynamo

$$Eff = \frac{E_m}{E_d} = \frac{e}{E}$$

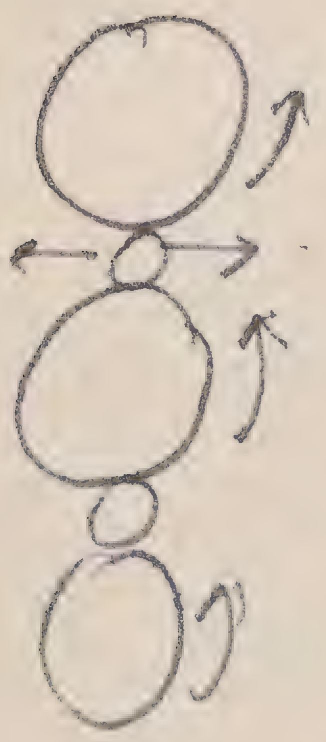
and the greater the counter EMF e, the greater the eff-

when e = E/2 this gives the condition for max. rate of work.

For the transmission of energy to considerable distances the higher the potentials the better we are off—

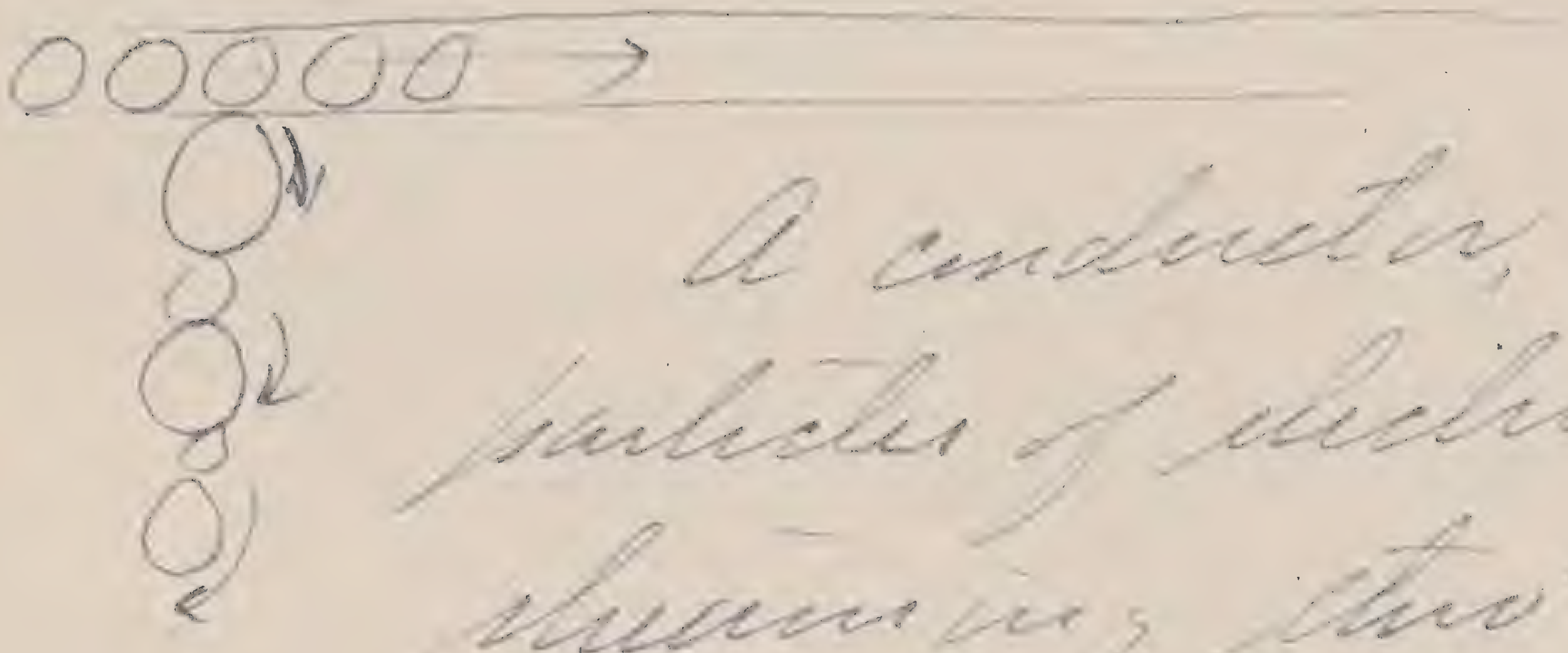
Electro-Mag. theory of light

Suppose we have a medium made up of two kinds of particles; electric and magnetic, so connected that any rotation of the one causes a rotation of the other.



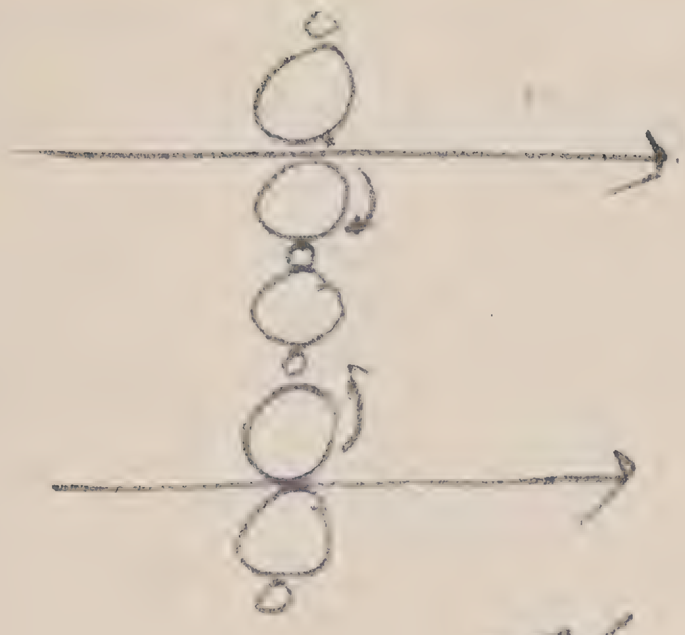
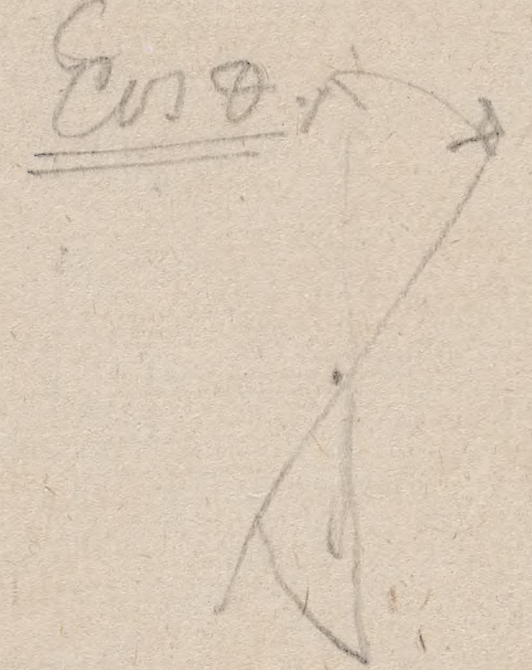
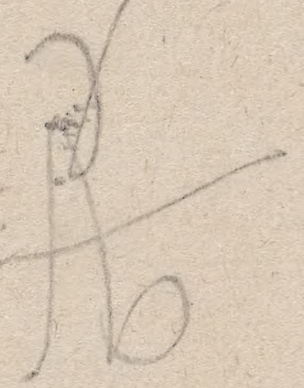
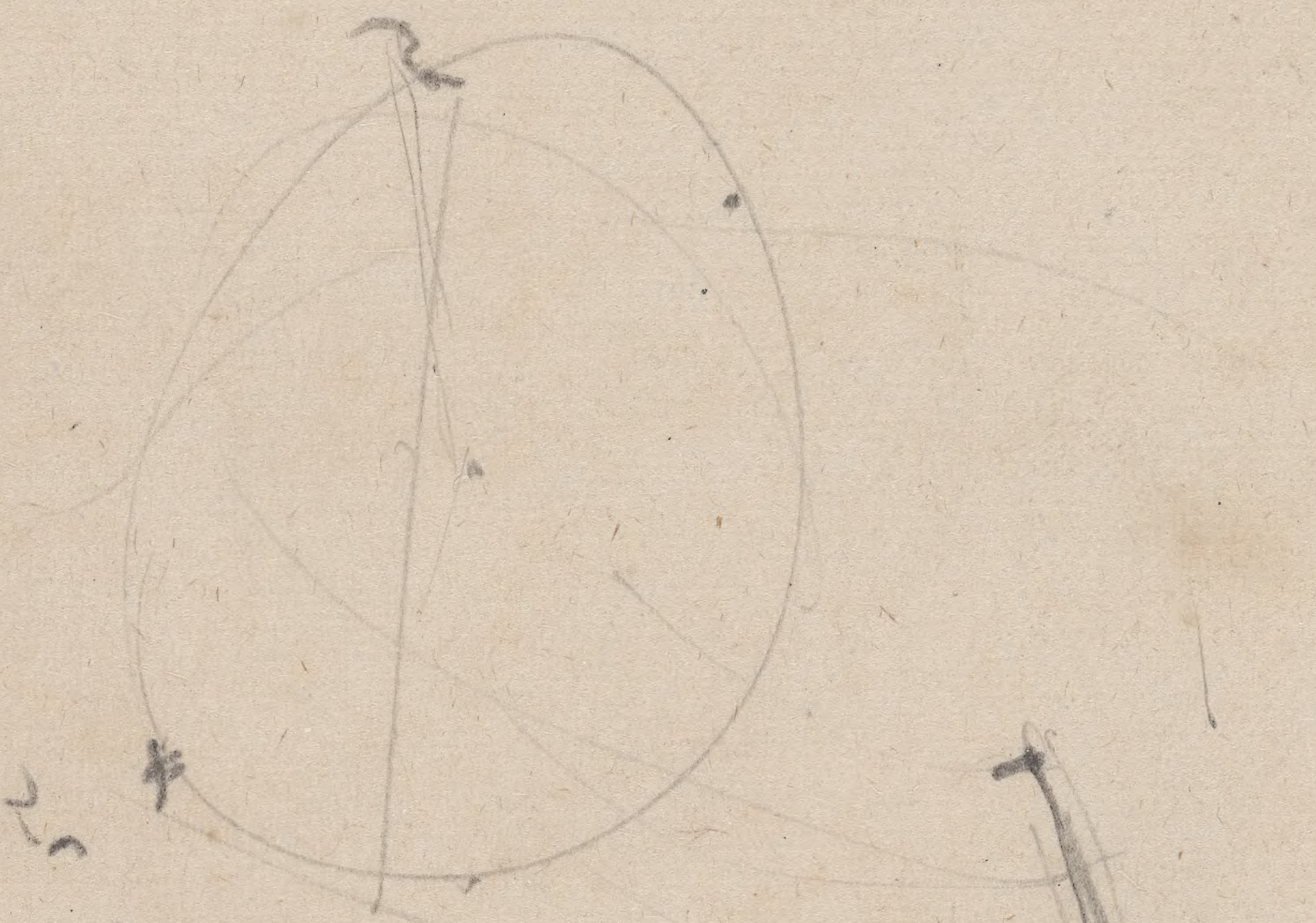
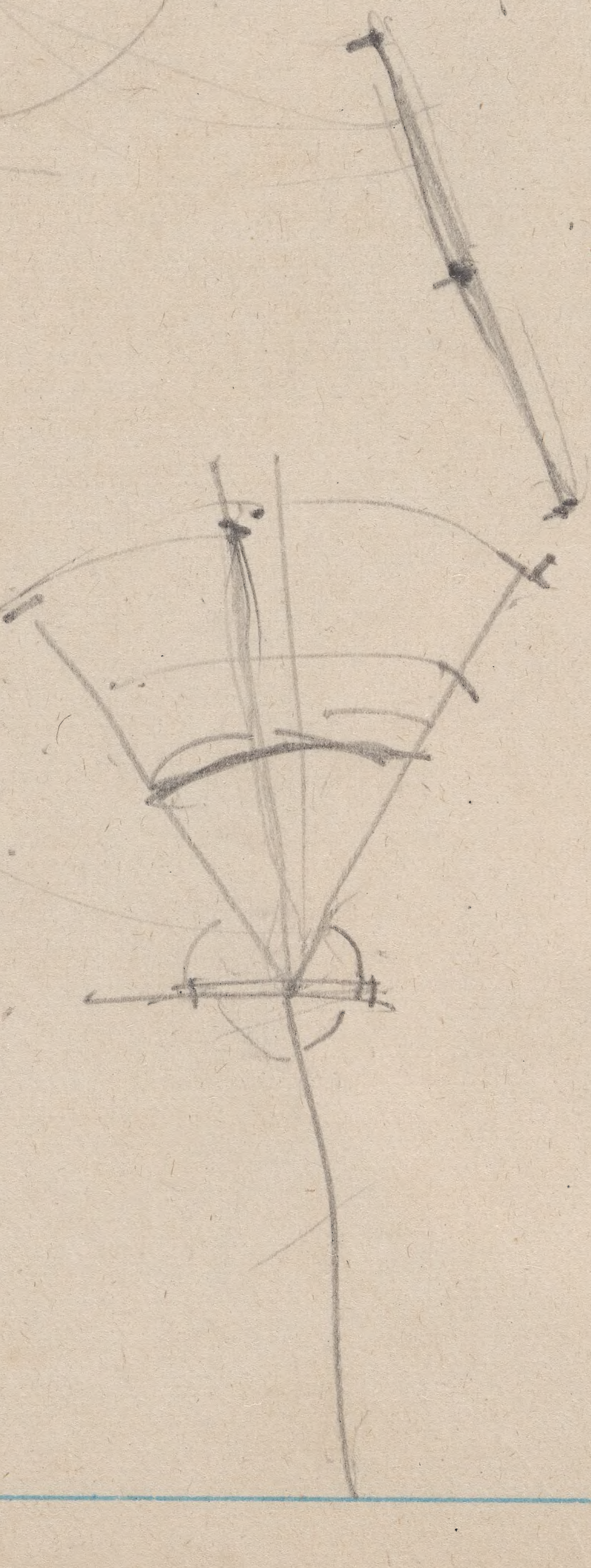
Now suppose in this system the small wheels may be displaced by a small amount, and the large wheels, the mag. system, to possess inertia. The smaller ones call electric, they always tend in a dielectric to come back to their original position: in a perfect conductor

no such rotation force –



A conductor, with particles of electricity streaming thro': they cause the energy system to rotate. Finally will have a steady condition; the energy of rotation will decrease outward. This system illustrates the field of force around a wire. The rotation would produce a tension along the line of force and a compression at rt ∠s to it.

Can explain by this method, the attraction of two wires



The pressure on outside of the two wires is greater than between: hence forced together